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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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tional Steelwork, shortly DISENGAGED owing to War work finishing; nine years' experience with well known London firm.—Address, F 157, Offices of Engineering.

Wanted, to Place Youth as

premium pupil with large firm of engineers near London. Apprenticeship five years, to include drawing office, combined with Technical School course.—F 126, Offices of Engineering.

HIGH-POWERED LOCOMOTIVES FOR THE PENNSYLVANIA RAILROAD.

(*Continued from page 246.*)

THE valve gears of both "K 4 S" and "L 1 S" classes of engine are of the Walschaert type and are practically identical except as regards the arrangements for connecting the lower end of the lap and lead lever to the crosshead. This difference in this respect is due to the difference in the designs of the crossheads used, and it will be at once understood on reference to Figs. 166 and 167, on page 256 of our issue of the 15th inst. In these views photographs of the front portions of the two classes of engine are reproduced.

The gear as fitted to the "K 4 S" class is shown in detail in Figs. 168 to 171, on Plate XXVI, all the chief dimensions being given. From these views it will be seen that the parts have been made as light as is consistent with the requisite strength. On account of the restriction placed on the design of these engines to the effect that the maximum weight desired per pair of wheels was 65,000 lb., with an absolute limit of 5 per cent. in excess of this figure, and a maximum vertical component of the unbalanced force of the reciprocating parts not exceeding 30 per cent. of the static load on rail, a special effort was made to keep the moving parts as light as possible. The result of this effort has been the development of parts of an "E 6 S" engine (a class with which we shall deal later) of the weights given below, similar results being obtained for the "K 4 S" and "L 1 S" classes:—

	Lb.
Piston and rod complete	408¼
Crosshead and pin	313
Piston valve complete (excluding valve stem)	119
Valve-stem crosshead	22
Lap and lead lever	33½
Lap and lead lever connector	11
Radius rod	119
Eccentric rod	49
Return crank	44½
Connecting rod	720
Side rod	417

The reversing gear is of the screw type and is shown in detail by Figs. 172 to 174, on Plate XXVI. This pattern of reversing gear is now standard on the Pennsylvania Railroad for modern locomotives in road service. It has been found quite satisfactory, the only trouble experienced being due to the wear of the nut. The end thrust of the screw is taken by a roller bearing.

In Figs. 175 to 180, on Plate XXVII, are given views of one of the main coupled wheels of the "L 1 S" class. The wheels are of cast steel and the chief dimensions are given in the views named. The design of the balance weight is noticeable. It will be seen that it is cast hollow with one face open so that the cavity can be thoroughly cleaned out. Subsequently the cavity is filled with molten lead, which is hammered in after the lead is cool so that the cavity is completely filled. The top of the counterbalance is then dressed off and a steel cover-plate riveted on. In some cases it has been found desirable to include on the cover-plate a heavy ledge, which adds to the counter-balance in wheels otherwise deficient in this respect. This type of counter-balance has been in use on the Pennsylvania Railroad for some time, with satisfactory results.

The crank-pins of all the locomotives under notice are made hollow, both to reduce the weight and to provide better opportunity for heat treatment. The crank-pin corresponding to the wheel above dealt with is shown in Figs. 181 to 186, on Plate XXVII, together with the return crank fitted to it. The crank-pin is 9 in. in diameter where it enters the wheel boss, and also at the inner bearing, while the outer bearing is 8 in. in diameter. A hole 4 in. in diameter extends the greater part of the length of the pin, the diameter of the hole for the rest of the length of the pin being reduced to 2½ in. The hole in the wheel boss receiving the pin is parallel except for the inner ¾ in. of its length, which is very slightly bell-mouthed, and the pin is secured by riveting over the end, as indicated in Fig. 186. In this figure the left-hand view shows the form of the end of the pin before, and the right-hand view after, riveting. The boss of the return crank, it will be noticed, is cut through on one side so as to give a spring fit to the end of the crank-pin, the desired grip being obtained by tightening up the bolt shown. The loose collar and bush for the pin of the return crank are shown in Figs. 184 and 185. The return crank is a drop forging and heat-treated.

With regard to the efficiency of these hollow crank-pins the photographs reproduced in Figs. 187 to 190, on Plate XXVII, are interesting. These photographs show a main crank-pin of the pattern above described, which was damaged owing to a connecting-rod brass breaking while an "E 6 S" type engine was running at a speed of about 70 m.p.h. Fig. 187 includes two general views of the damaged pin, while Fig. 188 more clearly indicates the effect of the hammering of the connecting-rod and the resulting flow of metal. Fig. 189 is a sectional view showing that the pin has been bent $\frac{1}{16}$ in. and also indicates the quality of the metal at different points in the pin. Fig. 190 shows a cross-section of the pin at the middle of the connecting-rod bearing, portions which were removed for test purposes not being shown. In Fig. 189 the letters A and B denote the location of microphotographs which were prepared, while the lines numbered 1, 2 and 3 show the positions from which test pieces were taken. The results of the tests were as follows:—

——	No. 1.	No. 2.	No. 3.
Elastic limit, lb. per sq. in... ..	60,440	66,620	66,150
Ultimate strength, lb. per sq. in. ..	98,310	112,470	112,730
Elongation, per cent. in 2 in. ..	29	26	27
Reduction of area, per cent. ..	56.9	48	50.8

Another example of the damage done to a main crank-pin by the breakage of a connecting-rod brass on an "E 6 S" locomotive when travelling at a high speed is illustrated in Figs. 191 and 192 on Plate XXVI. These photographs and those referred to above as a whole certainly indicate clearly the high qualities of the material used for these crank-pins and the efficiency of their heat treatment.

It may be of interest to give here the chief characteristics of the steel used by the Pennsylvania Railroad Company for their locomotive parts. For billets used in the manufacture of axles, crank-pins, main and side rods, piston rods and similar details from annealed carbon steel, quenched and tempered carbon steel, or quenched and tempered alloy steel, it is stipulated that the steel shall be made by the open-hearth process or other process approved by the General Superintendent of Motive Power and that the billets shall be made from ingots having at least four times their sectional area. Further the chemical composition of the billets is required to conform to the particulars given in the annexed Table I.

In the case of annealed carbon steel forgings made from the billets above mentioned it is stipulated that the minimum capacity of the hammer used in their manufacture shall be for forgings having the maximum diameters or thicknesses named, as follows:—For forgings up to and including 7½ in., 8,000 lb. hammer; for forgings over 7½ in. to and including 10 in., 10,000 lb. hammer; and for forgings over 10 in., 12,000 lb. hammer. The steel must also conform to the minimum requirements as to tensile properties given in Table II.

For quenched and tempered carbon steel forgings the requirements as regards the weight of hammers used in forging are the same as those given above for annealed carbon steel, but the chemical composition required is slightly different and is as follows:—

	Per cent.
Carbon	0.40–0.55
Manganese	0.40–0.70
Silicon	0.10–0.30
Phosphorus, not over	0.05
Sulphur „	0.05
Chromium „	0.30
Nickel „	0.40

The minimum requirements as to tensile properties demanded for this class of steel are given in Table III annexed, and unless otherwise specified axles, shafts and similar forgings are also given an impact test on a drop test machine with supports 3 ft. apart. The conditions imposed are:—The forging shall be struck two blows by a tup weighing 1,640 or 2,240 lb. falling from heights proportioned according to the subjoined formula, the forging being turned through 90 deg. after the first blow. The formula, in which D = diameter of forging at centre in inches, is as follows:—

Height of drop in feet = 0.01 D^3 for 1,640 lb. tup.
„ „ = 0.0073 D^3 for 2,240 lb. tup.

In the case of carbon steel billets used in the manufacture of various parts requiring a case-hardening treatment the steel is desired to have the following composition:—

	Per cent.
Carbon	0.20
Manganese	0.40
Phosphorus not above	0.04
Sulphur „	0.03

For the determination of the composition sample slabs are analysed according to the Pennsylvania Railroad standard methods, and material is taken from each sample slab as follows:—Diagonals are drawn across the cut-off end of the slab and a drilling taken on any diagonal at a point half-way between the centre and a corner, a ⅜ in. drill being used. The material represented by any sample

TABLE I.—*Composition of Steel Billets.*

Elements considered.	Carbon Steel.	Alloy Steel.	
		Chrome Nickel.	Chrome Vanadium.
	Per cent.	Per cent.	Per cent.
Carbon	0.40–0.55	0.28–0.42	0.28–0.42
Manganese	0.40–0.70	0.40–0.70	0.40–0.70
Silicon	0.10–0.30	0.10–0.30	0.10–0.30
Phosphorus, not over ..	0.05	0.05	0.05
Sulphur „ ..	0.05	0.05	0.05
Nickel „ ..	0.40	1.00–1.50	—
Vanadium	—	—	0.15–0.25
Chromium, not over.. ..	0.30	0.60–1.00	0.80–1.10

TABLE II.—TENSILE PROPERTIES OF ANNEALED CARBON STEEL FORGINGS.

Size.	Tensile Strength. Lb. per sq. in.	Yield Point. Lb. per sq. in.	Elongation in 2 in. Per cent.		Reduction of Area. Per cent.	
			Ratio.	Not under.	Ratio.	Not under.
Not over 8 in.	80,000	0.5 tensile strength	1,800,000 / Tens. str.	20	2,800,000 / Tens. str.	32
Over 8 in. to 12 in. inclusive ..	80,000	0.5 „ „	1,725,000 / Tens. str.	19	2,640,000 / Tens. str.	30
Over 12 in. to 20 in. inclusive ..	80,000	0.5 „	1,650,000 / Tens. str.	18	2,400,000 / Tens. str.	28

TABLE III.—TENSILE PROPERTIES OF QUENCHED AND TEMPERED CARBON STEEL FORGINGS.

Size.	Tensile Strength. Lb. per sq. in.	Elastic Limit. Lb. per sq. in.	Elongation in 2 in. Per cent.		Reduction of Area. Per cent.	
			Ratio.	Not under.	Ratio.	Not under.
Up to 4 in. in outside diameter or thickness; 2 in. max. wall	90,000	55,000	2,100,000 / Tens. str.	20.5	4,000,000 / Tens. str.	39
Over 4 in. to 7 in. in outside diameter or thickness; 3½ in. max. wall	85,000	50,000	2,000,000 / Tens. str.	20.5	3,800,000 / Tens. str.	39
Over 7 in. to 10 in. in outside diameter or thickness; 5 in. max. wall	85,000	50,000	1,900,000 / Tens. str.	19.5	3,600,000 / Tens. str.	37

is rejected if the analysis of the boring taken at the point named shows :—

(*a*) Carbon below 0.15 per cent. or above 0.25 per cent.
(*b*) Manganese below 0.30 per cent. or above 0.50 per cent.
(*c*) Phosphorus above 0.05 per cent.
(*d*) Sulphur above 0.05 per cent.

trailing truck, as in the case of the "K 4 S" type. We may mention here that according to Pennsylvania Railroad practice the springs are designed so that the plates are straight when free from load. The springs have thus a reverse curvature when under working conditions.

The steel used for plate springs by the Pennsylvania Railroad Company is desired to have the following composition :—

	Per cent.
Carbon	1.00
Phosphorus, not above	0.003
Manganese, not above	0.25
Silicon, not above	0.15
Sulphur, not above	0.03
Copper, not above	0.03

Springs, however, are accepted if on analysis the steel of which they are made contains not less than 0.90 per cent. and not more than 1.10 per cent. of carbon and the other constituents do not exceed the following amounts :—Phosphorus, 0.05 per cent. ; manganese, 0.50 per cent. ; silicon, 0.25 per cent. ; sulphur, 0.05 per cent. ; and copper, 0.05 per cent.

In Figs. 193 to 197, annexed, we illustrate the brake gear fitted to the "L 1 S" type of engine. On such heavy locomotives it was found desirable to apply two driver's brake cylinders 16 in. in diameter, thus maintaining a proper ratio between the brake-cylinder pressure and the shoe pressure on the wheels. On account of the size of the frames, however, and the short distance between their tops and the boiler, the two brake-cylinders could not be placed side by side, as is the standard practice. One cylinder, therefore, is placed horizontally and the other vertically, as shown in Fig. 193, the pistons being connected to cylinder levers of proper design to act on the same fulcrum shaft. This arrangement which, with the other details of the brake gear, is clearly shown in our illustrations, has been found entirely satisfactory and quite convenient from a repair standpoint.

(To be continued.)

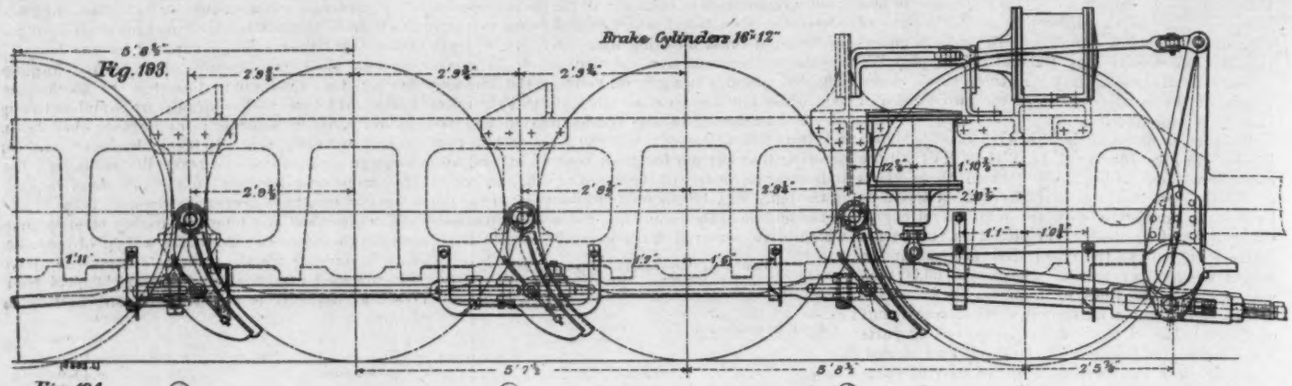


Fig. 193.

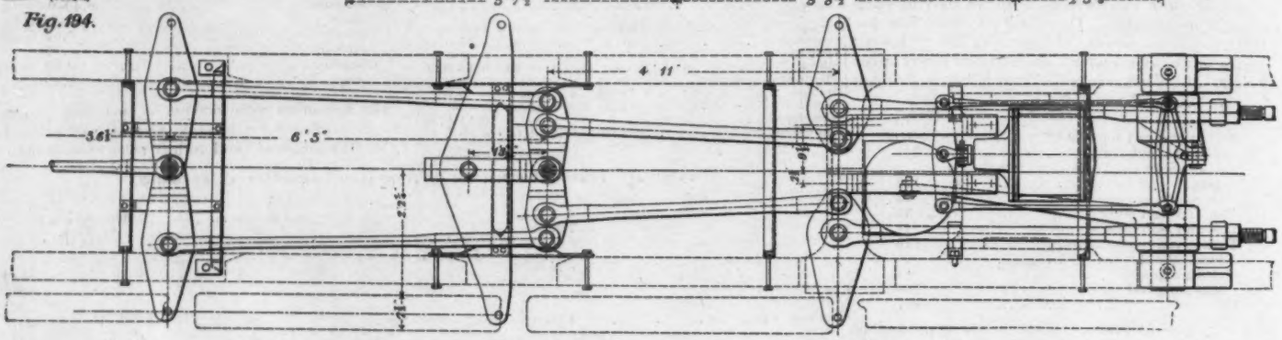


Fig. 194.

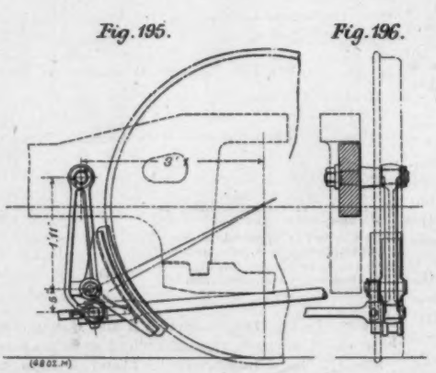


Fig. 195.

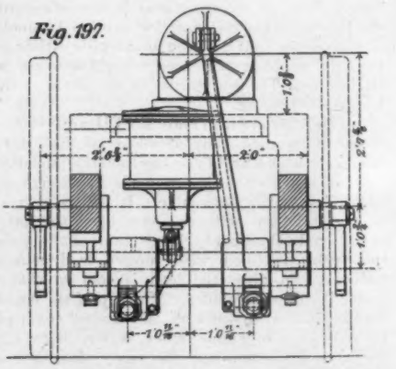


Fig. 196.

Fig. 197.

The sample slabs above referred to are obtained as follows :—If any delivery of steel represents a single melt of 10,000 lb. or less one billet is selected at random and a slab 1 in. thick is cut from the end. If the melt represented is over 10,000 lb., but less than 20,000 lb., samples are taken from two billets, and above 20,000 lb. a sample is taken from an additional billet for each increment of 10,000 lb. in the weight of the melt.

As stated at the commencement of these articles, and as shown by Figs. 1 and 5 on pages 98 and 99 *ante* both the classes of engine we are describing are fitted with trailing trucks supporting the fire-box end. In our issue of February 26, 1915, page 249, we discussed the effect on American locomotive design effected by the introduction of the trailing in main line practice, and later, in a short series of articles,* we gave an account of the chief types of such trucks in use in the United States. Amongst these we described and illustrated in full detail in our issue of June 25, 1915, page 701, the present standard trailing truck of the Pennsylvania Railroad, that being the truck fitted to the two types of locomotive with which we are now dealing. This being the case, it is unnecessary for us to repeat the description here.

At the leading end the "K 4 S" type of engine is fitted with a four-wheeled truck of the pattern which we fully described and illustrated in our issue of July 30, 1915, page 108, when we also explained the system of equalising the loads between the truck and the leading pairs of coupled wheels. The springs of the central and rear pairs of coupled wheels are also connected by equalising beams, while the loads of the hind pair of coupled wheels are further equalised with the trailing truck. In the case of the "L 1 S" type of engine the front end is carried on a two-wheeled truck, and the load on this truck is equalised with that on the first and second pairs of coupled wheels. The springs of the third and fourth pairs are equalised with the

* *Vide* ENGINEERING, vol. xcix, pages 621, 650 and 701.

THE INSTITUTION OF MUNICIPAL AND COUNTY ENGINEERS.—On Saturday, October 7, there will be a meeting of the Institution at Watford, at 11.30 a.m. ; a paper by Mr. D. Waterhouse on "The New Water Supply and other Municipal Works at Watford" will be taken as read, and discussed. In the afternoon the members will visit the new pumping station and softening works and the sewage pumping station, destructor and electricity works.

AMERICAN BOILER INSPECTION.—All steam boilers in Pennsylvania carrying pressure greater than 15 lb. per square inch are to be thoroughly inspected every year under working conditions, according to rules made recently by the Industrial Board of the Department of Labour and Industry. Boilers subject to inspection under federal laws are exempted from inspection, as well as boilers on automobiles and fire engines brought into Pennsylvania for temporary use. Boilers carrying less than 15 lb. per square inch pressure must be equipped with safety devices approved by the Industrial Board.

THE BRITISH ASSOCIATION.

(Continued from page 276.)

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

THE proceedings of Section A quite maintained their high level, though the meteorologists had to completely absent themselves, and several of the members whose participation in the discussions was anticipated in the provisional programme, issued on the first day of the meeting, were finally prevented from attending. Among these latter were Professor G. E. Hale, from the Mount Wilson Observatory, California, and Mr. J. Evershed, from the Kodaikanal Observatory, India. The list of papers was not long, but it required three morning sittings and two afternoon sittings (once in two departments) to dispose of them. The discussion on Gravitation dealt with fundamental problems in a thoroughly instructive manner.

The Section met in the Trinity Presbyterian Church Rooms under the presidency of Professor A. N. Whitehead, Sc.D., F.R.S., of the Imperial College of Science, South Kensington, who did not waste time on merely complimentary votes of thanks. The Vice-Presidents were: Sir Frank W. Dyson, F.R.S. (the Astronomer Royal), Professor T. H. Havelock, F.R.S., of Newcastle, and Sir Ernest Rutherford, F.R.S. The Secretaries: Professor A. S. Eddington, F.R.S. (of Cambridge Observatory, Recorder); Drs. H. R. Hassé and W. Makower, M.A., of Manchester University; A. O. Rankine, of University College, London; and G. M. Caunt, M.A., of Armstrong College.

THE ORGANISATION OF THOUGHT.

The remarkable address delivered by Professor A. N. Whitehead, probably has, in the strict sense, no predecessor in the annals of the Section. In the breadth of the lines of thought it recalled the addresses of Professor Horace Lamb at Cambridge in 1904 and Professor Poynting at Dover in 1899. "There are very few mathematicians in this country," Major MacMahon remarked, in proposing the vote of thanks to the president of the Section, "competent to comment on this address by one of the deepest thinkers in the country, and even to mathematicians the symbolism of those few is a new alphabet." Such an address must be studied; it will be very difficult to outline its arguments.

The subject—the organisation of thought—Professor Whitehead said, was a topic evidently capable of many diverse modes of treatment. It was no accident that an age of science had developed into an age of organisation. Organised thought was the basis of organised action, organisation the adjustment of diverse elements so that their mutual relations might exhibit some predetermined quality. An epic poem, in the unlikely event of its being a good epic poem, was a triumph of organisation. Science, the organisation of thought, had two sources, neither more noble nor intrinsically more interesting than the other: the practical source, the desire to direct our actions to achieve predetermined ends, and the theoretical source, the desire to understand. Both sources existed in all men. The importance, even in practice, of the theoretical side of science arose from the fact that action must be immediate and took place under circumstances which were excessively complicated. "If we wait for the necessities of action before we commence to arrange our ideas, in peace we shall have lost our trade, and in war we shall have lost the battle."

What was the actual world for the purpose of science? Science had not to wait for the termination of the metaphysical debate to determine its own subject-matter; it had a much more homely starting-point. The panorama yielded by sight, sound, taste, smell, touch and by more inchoate sensible feelings was the sole field of its activity, and in this way science was the thought organisation of experience. The most obvious aspect of this field of actual experience was its disorderly character. It was for each person a *continuum*, fragmentary, and with elements not clearly differentiated. "I insist on the radically untidy, ill-adjusted character of the fields of actual experience. To grasp this fundamental truth is the first step in wisdom when constructing a philosophy of science. This fact is concealed by the influence of language moulded by science, which foists on us exact concepts as though they represented the immediate deliverances of experience. The result is that we imagine that we have immediate experience of perfectly defined objects implicated in perfectly defined events which happen at exact instants of time in a space formed by exact points, without parts and without magnitude: the neat, trim body, exact world, which is the goal of scientific thought. . . . The question I invite you to consider is: How does exact thought apply to the fragmentary, vague *continua* of experience. I am not saying that it does not apply, quite the contrary. . . . I emphasise two points. In the first place, science is rooted in the whole apparatus of common-sense thought. That is the *datum* from which it starts and to which it must recur. In the second place, neither common-sense nor science can proceed with the task of thought organisation without departing in some respect from the strict consideration of what is actual in experience. . . . Science is essentially logical, a permanent record of premises, deductions, conclusions verified all along by its correspondence with facts. It is untrue that when we know the premises we also know the conclusions."

Proceeding, Professor Whitehead discerned four departments or sections of logical theory, which he called the arithmetic section, the algebraic section, the section of general-function theory, the analytic section. He did not mean that arithmetic arose in the first section, algebra in the second, &c.; the names were suggestive of certain qualities of thought analogous to arithmetic, &c. The first section dealt with the relations of definite propositions to each other as arithmetic dealt with definite numbers. "Consider any definite proposition, call it '*p*.' There is always another proposition, the direct contradictory to '*p*'; call it 'not-*p*.' When we have two propositions, *p* or *q*, we can form derivative propositions from them and from their contradictories. We can say: at least one of *p* or *q* is true, or perhaps both. Let us call this proposition '*p* or *q*.' . . . We have thus got hold of four new propositions, namely *p* or *q*, not-*p* or *q*, and *p* or not-*q*, and not-*p* or not-*q*." Calling these the set of disjunctive derivatives of the original four propositions (*p*, not-*p*, *q*, not-*q*), Professor Whitehead obtained eight propositions and so on, any of which might be true or false. The first section of logical inquiry was to settle what was known of their truth-values when the truth-values of some of them were known.

In the algebraic section, he continued, symbols or letters were standing for any numbers; they were called variables or parameters and were undetermined unless the algebraic conditions which they satisfied implicitly determined them. The proposition: "the specific heat of mercury is 0.033" would be definite and, with certain limitations, true. To say: "the specific heat of *x* is 0.033" was not a proposition, but had been called a propositional function by Russell. Generalising further, it would be: the specific heat of *x* is *y*, and we should have a propositional function F (*x*, *y*) of two arguments *x* and *y*. Considering only *f* (*x*), there would be a range of values of *x* for which *f* (*x*) as a proposition was true or false. For values of *x* outside this range *f* (*x*) would not be a proposition at all, and would neither be true nor false. For instance, to assert: "the specific heat of water is 0.033 deg.," was false; to say: "the specific heat of virtue is 0.033," would not be a proposition at all, and neither true nor false, though it might raise various associations in our minds. In pursuing these arguments further, Professor Whitehead referred to the brillant work on the theory of types by the Hon. Bertrand Russell (co-author with Professor Whitehead of the *Mathematica Principia*), and to the logical variables of Frege and of Peano.

We cannot attempt to follow Professor Whitehead through his characterisation of the third logical section, the stage of general-function theory, and the fourth analytic stage, which, he explained, included the whole of mathematics, developed from the concepts of class and correlation. He had himself to confine himself to the briefest outline in his address. But we will refer to some of his concluding remarks. What were the points composing space? According to Euclid they were without parts and magnitude. But our knowledge of space properties was not based upon any observations of relations between points; it arose from experience of relations between bodies. Now a fundamental space relation between bodies was that one body might be part of another. We were tempted to define the "whole and part" relation by saying that the points occupied by the part were some of the points occupied by the whole. But whole and part being more fundamental than the notion of point, that definition was circular and vicious. Professor Whitehead suggested the following consideration, though it would be unessential to his general arguments if he were mistaken. "We have come to the conclusion that an extended body is nothing else than the class of perceptions of it by all its percipients, actual or ideal. The perceptions of a part of a body are among the perceptions which compose the whole body. Thus two bodies, *a* and *b*, are both classes of perceptions; and *b* is part of *a* when the class which is *b* is contained in the class which is *a*. It immediately follows from the logical form of this definition that, if *b* is part of *a*, and *c* is part of *b*, then *c* is part of *a*. Thus the relation 'whole to part' is transitial. Again, it will be convenient to allow that a body is part of itself. This is a mere question of how you draw the definition. With this understanding, the relation is reflexive. Finally, if *a* is part of *b* and *b* is part of *a*, then *a* and *b* must be identical. These properties of 'whole and part' are not fresh assumptions, they follow from the logical form of our definition."

We confess we feel perplexed. But since Professor Lamb, who seconded the vote of thanks, admitted that he had not hoped to follow much of the discourse, such confessions are hardly called for. Professor Lamb further questioned whether a statement like "the specific heat of mercury is 0.033" could be called true; we could only say that somebody had asserted it.

GRAVITATION AND RELATIVITY.

The discussion on "Gravitation" was opened by Mr. E. Cunningham, of St. John's College, Cambridge, in a masterly discourse. We have ventured to add Relativity to the title, because the discussion touched very largely on the latest generalisation of the principle of relativity.* Mr. Cunningham pointed out that the enunciation of the law of gravitation and the birth of the science of dynamics were inseparably related. Yet while Newtonian dynamics had been the guiding principle in physical thought during the two centuries behind us, little more was known of gravitation now than Newton knew. Gravitation had eluded investigation and analysis and remained isolated. The few experimental results obtained had on the whole been favourable to the Newtonian conception. It had been shown with great accuracy that the constant of gravitation was independent of the nature of the attracting masses; that crystalline bodies were isotropic as far as their power of attracting other bodies was concerned; there were, on the other hand, some slight indications that the attraction of a chemical compound might not exactly be equal to the sum of the attractions of the components; and there was evidence of a considerable change in the attraction exerted by a body when heated (P. E. Shaw). By far the most convincing and exact information of the inverse square law had been furnished by astronomy; but astronomical observations had also revealed the outstanding anomaly in respect to gravitation of which, he understood, Professor Eddington would speak.

For some time the laws of electricity had appeared to supply a basis for all physical phenomena. But positive electricity had not yet yielded up its secret, and the outstanding puzzle of radiation and that strange new thing, the quantum theory, made us feel how far we were from a comprehensive knowledge of the constitution of matter. The electro-magnetic theory was further than ever from giving a detailed explanation of the results of experiments which led to the enunciation of the

* We would refer our readers to the recent general article on this subject in our issue of August 11, pages 132–134.

principle of relativity; that became all the more important, therefore, as an independent hypothesis. Meanwhile, the fact of gravitation, the fundamental fact of matter in bulk, independent of all unexamined diversity in the constitution of the chemical elements, had almost been forgotten among the exciting revelations of the laboratory. We were not in a position at present to rest an understanding of the forces of gravitation on an intimate knowledge of the constitution of matter. The problem might be approached under two aspects: (1) consideration of the centres of gravitation, and (2) of the field of gravitation. As regards the second, Laplace had asserted that, if gravitation were propagated through space with a finite velocity, that velocity must be infinitely greater than the velocity of light. But many ways had been proposed of reconciling astronomical data with a velocity of propagation equal to that of light, the stimulus to these attempts lying, of course, in the hope of an electrical theory of matter. We thought no longer in terms of instantaneous action at a distance and no longer of the inverse square law as the last word on the subject. On both grounds we were prepared for a specification of the gravitational field. That field required for its representation more than a simple potential function, just as the electro-magnetic field was specified by vectors (the electric and magnetic forces), and not by a single scalar potential like the electrostatic field.

Passing to the first aspect, the dependence of gravitation upon the mass of attracting and attracted bodies, Mr. Cunningham pointed out that, until recent years, the mass of a body had been considered as a fundamental concept, a fixed quantity. Now, however, part, if not the whole, of the inertia was attributed to electrical origin. It was generally accepted that incident radiation increased the energy of a body by E/c^2, where c was the velocity of light, and that a hollow vessel filled with temperature radiation had inertia by virtue of that radiation. Since, however, the mass of the negative electrons—the only bodies whose mass we could confidently assert to be purely electro-magnetic—was only a small part of the mass of the atom, we were bound to consider now the possibility that gravitation might be confined to inertia of a different, unexplained kind located in the nuclei of the atoms. Yet Eötvös, in some of the most accurate experiments carried out, came to the conclusion that the gravitational force of a body was proportional to its dynamical mass within 1 in 2×10^7, and the variations in the proportion of the mass of the negative electrons in any substance to the whole mass were certainly much greater than this. Thus it appeared probable that gravity might affect the purely electro-magnetic mass (which found its explanation in the electric field about the electrons), and the energy of radiation within a body would contribute to its gravitational mass. To say [as Einstein does] that a beam of light had weight, was only a short step from this.

Einstein had tried to make this more precise with the aid of the principle of equivalence. If we were in a lift descending with acceleration, the apparent effect of gravitation would be diminished, and it would disappear entirely if we were falling freely. Conversely, an upward acceleration would increase the apparent magnitude of gravitation. In the same way the acceleration of a point on the earth's surface due to its rotation affected the apparent value of gravitation at that point. Generally the effect of a uniform gravitational field was exactly the same as the effect of giving, to every point of the system, a certain acceleration in the opposite direction; that was the principle of equivalence for mechanical phenomena, and this equivalence might be applied to gravitation as affecting electrical phenomena. To the person inside the lift (unconscious of external phenomena), there was no apparent gravitation. Relative to the *falling lift* there would similarly be no electrical disturbance, the ordinary laws of electro-magnetism would apply, and light would be propagated uniformly with equal velocity in all directions. It was, then, only a matter of geometry to describe the same phenomena as they would take place relative to an outside observer not in the lift. To the man in the lift, *e.g.*, a horizontal ray of light would appear straight of uniform velocity c; to the man outside the light would travel horizontally with velocity c, and with downward acceleration g, and the ray would be curved, the curvature being g/c^2. The downward curvature would show (Huygens) that the velocity of light increased with height, approximately according to the formula (Einstein) $c = c_0 (1 + \phi/c_0^2)$ where c_0 was the velocity of light in a field free from gravitation and ϕ was the ordinary gravitational potential. Where gravitation was apparent the velocity of light would no longer be constant. Attempts to observe this bending of a ray of light—which should amount to 1.7 second of arc for a ray passing the sun tangentially—by observing a star close to the sun at the time of a total eclipse, were to have been made in August, 1914; but political and meteorological conditions rendered this impossible.

The velocity of light should, according to Einstein, also be varied along a ray. If light of frequency ν (as observed at a point A) were passing from A to B, there being a gravitational field g in the direction B A, the effect (by the principle of equivalence) would be the same as if there were no gravitation, but both A and B had an acceleration in the direction A B. Assuming the velocity of A B to be zero when a certain wave reached A, then that wave, reaching B after the time A B/c, would have a velocity g . A B/c in the direction of the light, and the frequency ν (as observed at B) would by Doppler's principle be $\nu (1 - g$. A B/$c)$; there would result a change of frequency $\delta\nu = -\nu\,\delta\phi/c$. Applied to light coming from the sun to the earth, this change in period would amount to 2×10^{-6}, ϕ indicating the change in potential in passing from the sun's surface to the earth. The lines of the solar spectrum should correspondingly be displaced with regard to lines of a terrestrial source; that displacement was known, but was commonly attributed to a pressure effect. The following tables of E. Freundlich show that it is quite possible that the displacement effect actually exists:—

Wave-Length.	Displacement Observed.	Calculated.
I. 4040	+0.0078	+0.0081
I. 4500	+0.0071	+0.0090
I. 5170	+0.0093	+0.0103
II. 4250	+0.0062	+0.0085
II. 5300	+0.0103	+0.0106

The wave-lengths concerned groups chosen because only slightly susceptible of a pressure shift; the calculations were based on Einstein; the observations I. were made by J. Evershed [of Kodaikanal, who had a paper on "Kashmir Spectro-Heliograms" on the list, but was unable to attend at Newcastle], and those of II. by Fabry and Buisson.

Professor Eddington, rising after Mr. Cunningham, said that there had been rumours of a revolutionary advance by Einstein in the relativity theory of gravitation, but detailed information had not been obtainable; Professor W. de Sitter [Leiden] had now sent him Einstein's recent paper (*Annalen der Physik*, vol. XLIX, June, 1916) and papers of his own. The elaboration of the theory of relativity, Mr. Eddington stated, would not under any circumstances be a waste of time, because whether it contained any physical truth or no, it contained far-reaching mathematical truths. But Einstein's theory had a strong claim to our acceptance as a physical truth, because it explained with numerical exactness and without introducing any new constants an important astronomical phenomenon which had hitherto baffled explanation. He (Ed-

RAIL-BREAKING MACHINE.

CONSTRUCTED BY THE COVINGTON MACHINE COMPANY, COVINGTON, VIRGINIA, U.S.A.

(*For Description, see Page* 300.)

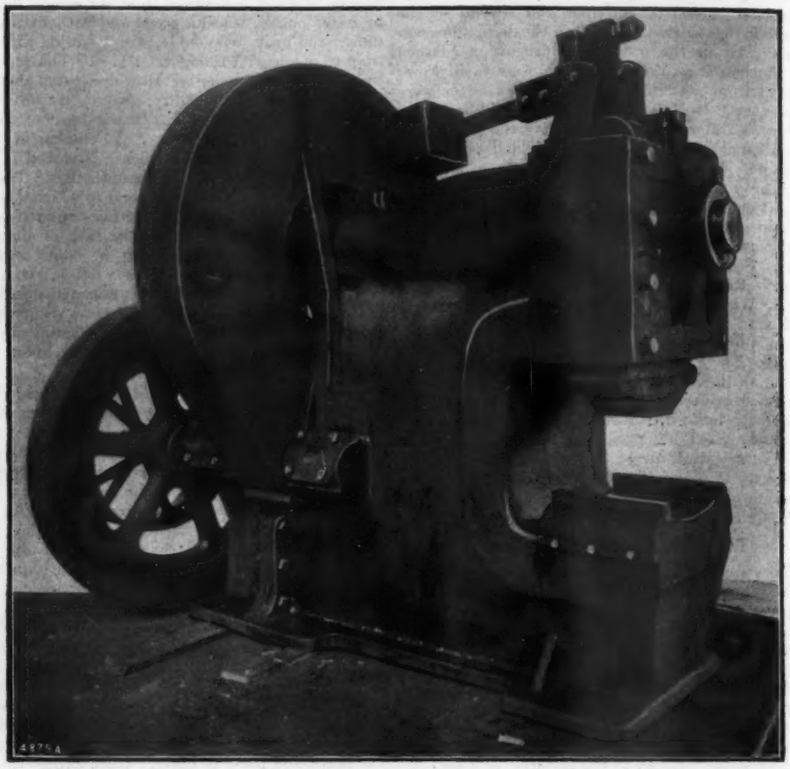


FIG. 1.

PUNCHING MACHINE FOR STEEL RAILS.

CONSTRUCTED BY THE COVINGTON MACHINE COMPANY, COVINGTON, VIRGINIA, U.S.A.

(*For Description, see Page* 300.)

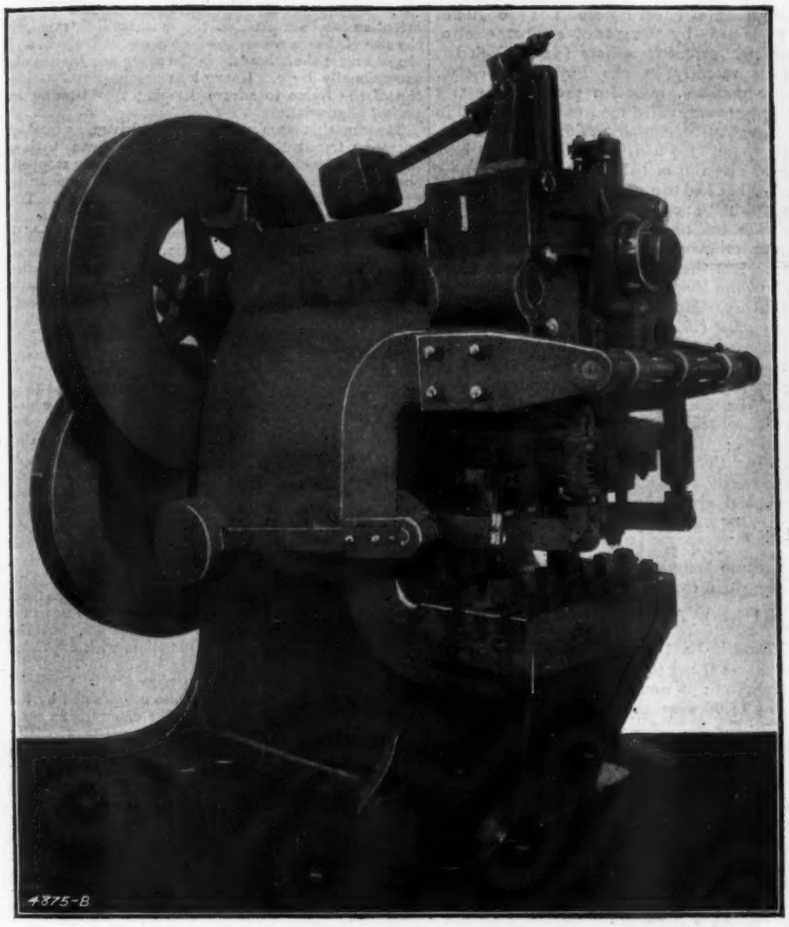


FIG. 2.

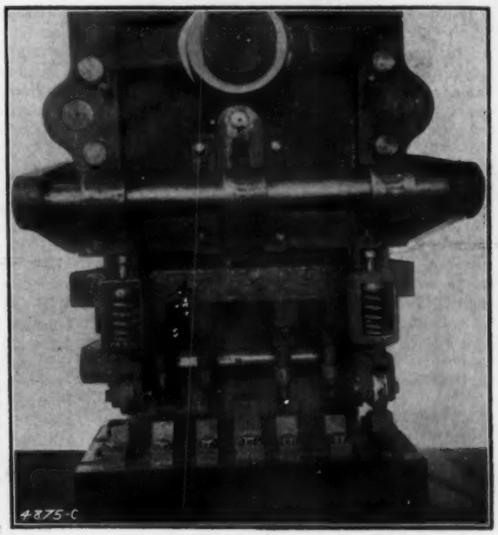


FIG. 3.

dington) found his triumph so overwhelming that it was difficult to preserve the proper attitude of scepticism. Einstein's theory was not an attempt to explain gravitation—as a kink in space or anything of that sort; it was an attempt to determine the more general law of gravitation, to which Newton's law was a close approximation in the usual case when bodies were at rest or moving with speeds slow compared with the velocity of light. The form of the law of gravitation might well be determined by the properties of space. The inverse square law represented the natural weakening of an effect by spreading it out in three dimensions especially appropriate to Euclidean space.

Supposing space and time of a point P were measured with respect to four co-ordinates x_1, x_2, x_3, x_4, of which x_4 referred to time, which need not be discriminated from space. The gravitational field at P could be abolished by choosing new axes (accelerated with respect to the first) x_1', x_2', x_3', x_4'; that, of course, would only get rid of gravitation at the one point, unless the field happened to be uniform. The necessary transformations might be specified in various ways, for instance, by

$$d s^2 = d x_1'^2 + d x_2'^2 \ldots$$
$$\ldots = g_{11} d x_1^2 + g_{22} d x_2^2 + \ldots 2 g_{12} d x_1 d x_2,$$

the cube terms being negligible. The g-factors specified the transformation and the metric properties without regard to orientation; they specified, moreover, the gravitational field, at least in showing how to get rid of the field. There would be ten of these g, varying from point to point of space and time; they were called gravitation potentials, and one of them, g_{44}, would be a first approximation to the Newtonian potential ϕ. The new law of gravitation would then be expressed as a set of equations to be satisfied by the g. The inverse square law was equivalent to the equation of Laplace—

$$\frac{\delta^2 \phi}{\delta x^2} + \frac{\delta^2 \phi}{\delta y^2} + \frac{\delta^2 \phi}{\delta z^2} = 0$$

and the task was to find the generalised equivalent involving ten potentials instead of one.

There the principle of relativity was appealed to. For out-and-out relativists the space and time of physics were apparently only a mental scaffolding to locate observable phenomena, the scaffolding itself not existing outside our brains. The possible sets of relations between the g, which would remain satisfied for any alteration of co-ordinates whatever, were very limited in number; they were enumerated by the theory of "tensors" worked out by Riemann, Christoffel and others. It might be surprising that the possible laws were so limited; but it was even more surprising perhaps that there should exist any set of equations at all invariant for every conceivable change of co-ordinates. The principle of relativity left only a very limited choice of laws, and from those we had to pick out one which reduced to $\nabla^2 g_{44} = 0$, as an approximation in ordinary problems; that last condition reduced the choice to exactly one which Einstein adopted as expressing the generalised law of gravitation. It was important to notice clearly how much was mere geometry, and how much a new law of nature. Geometry told us that, *if* those equations held for one set of co-ordinates, they would hold for every set. "We abolish the *if*, and in so doing assert a law of nature."

So much, Professor Eddington continued, for the gravitation field in free space. There remained the question, What was to be the equivalent for Poisson's equation $\nabla^2 \phi = -4 \pi \nu$ [where ν is the mass density] which applied to space where matter was present. Einstein solved this very simply. A certain expression T in the ten equations could be identified as the energy of the gravitational field, and then the ten equations really expressed the principle of least action. Calling the electro-magnetic energy E, Einstein said that the only difference made by the presence of matter was that this extra energy E was knocking about in addition to T, so that one had to write T + E instead of T. This was justified because both gravitational and electro-magnetic energy behaved similarly in regard to the principle of least action. Neither T nor E were scalar quantities, both being tensors with ten components. Professor Eddington could not write down the equations, as the explication of the notation would alone take quite half-an-hour, but he referred to the results verified.

When a planet was moving in an ellipse the ellipse rotated in the direction of motion at the rate of $24 \pi^3 a^2/T^2 c^2 (1-e)^2$ per revolution of the planet, which expression was practically $6 a^2/c^2$, a being the large semi-axis, c the velocity of light, e the eccentricity, and T the time of the orbit. Working that out for Mercury, the result was 43 seconds per century, just the observed value for the movement of the Mercury nodes, which so far had been unaccounted for. The only suggestion hitherto made for its explanation was that the effect was due to the mass of matter constituting the Zodiacal Light; but the necessary mass seemed improbably great. The formula gave a rotation of 8.6 seconds for Venus and of 3.8 seconds for the Earth; but the orbits of these planets were so much less elliptical than that of Mercury, that our knowledge of the rate of rotation was far less accurate, which could hardly be detected in these cases. It would be noticed that the formula contained only astronomical elements and the velocity of light; Einstein had found his generalised law of gravitation from

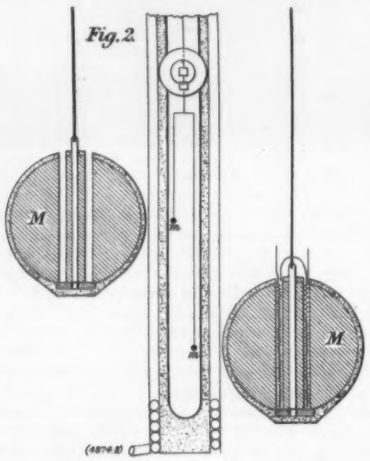
pure theory, and applying it to this special case, the beautiful result had dropped out.

Sir Frank W. Dyson, who spoke next, confined himself to a few guarded remarks. They had not yet access to the details of these striking researches. The astronomical observations in question at eclipses were not impossible, but extremely difficult. There was certainly an anomaly in the movement of the nodes of Mercury; but there were similar anomalies as to Venus and the Moon, wholly unexplained so far, though E. W. Brown, of Yale College, and others, believed they had traced all gravitational effects.

Gravitation Constant and Temperature.

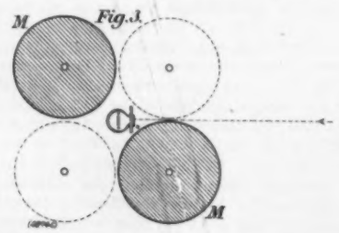
Dr. P. E. Shaw, of Nottingham University College, next called upon, gave a brief account of the remarkable experiments which he has been conducting for several years in a vault of the Physics Department of the college with a Cavendish balance for the purpose of determining a possible temperature coefficient of gravitation, his temperature range being + 15 to 250 deg. C. In his experiments, which, of course, required the most extraordinary care, Dr. Shaw has used various arrangements and materials; Figs. 2 and 3 explain the devices finally

Fig. 2.



adopted. Within an exhausted glass tube, 120 cm. high, 5 cm. in diameter, were suspended from a short beam and a torsion head by quartz fibre, almost too delicate for the disturbed load, two small silver balls, m, weighing 3 grammes each; immediately outside the tube, also at different heights corresponding to the levels of the small balls, were suspended by copper wires two lead balls, M, each 20 cm. in diameter and weighing 47 kg. The tube was exhausted by a Gaede pump and lagged with cotton wool, a water-jacket and again cotton wool (outside lagging not marked in diagram); a mirror was attached to the fibre to take readings through an optical window by means of a telescope. The lead system could be swung round through 90 or 180 deg. on its turn-table; when this was done (Fig. 3) the big balls M attracted the small balls m

Fig. 3.



from the opposite sides, and tended to turn the beam out of its former position of rest, causing a deflection of the torsion system. When the balls M were moved, the scale reading changed by 200 millimetres in the experiments at 15 deg. C., but when the temperature was 215 deg. the change observed was 200.4 mm. Heating coils could be inserted into vertical holes drilled through the balls M, but these coils were always removed before taking a reading of the torsion system. Plotting the range of attraction against steady, falling, or rising temperature, Dr. Shaw obtained somewhat irregular curves, yet showing unmistakably that the attraction increased as the temperature rose. There was certainly a temperature effect; but was it a gravitation-temperature effect? He had to guard, as he explained by diagrams, against electrostatic effects, magnetic effects (with which Dr. Shaw dealt recently in the Physical Society), radiometric pressure, radiation pressure (for this reason a gas pressure of 14 mm. was maintained in the tube), convection, damping, stiffness and torsion of the wires, &c. He had first attempted to heat both the M and the m balls and the intervening medium, but had had to give that up, and had heated only the lead balls, near which powerful convection currents were set up. In most previous direct experiments ordinary constant temperature had been used. But there ought to be a temperature coefficient of the Newtonian constant according to the wave theory of Morozov (1903) and the theory of matter of G. Mie (1913), whilst Bohr assumed that gravitation would not be affected by physical and chemical agencies, being, like radio-activity, a nucleus property. Poynting and Phillips had in 1913 counterpoised a mass of 208 grammes on a balance and varied its temperature between + 100 and − 186 deg. C.; the resulting change in weight, if any, was less than 10^{-9} per deg. C. In Poynting's experiment the Earth was the big ball M, and he had given the formula, force observed, $f = g\left[1 + a\,\frac{M\,t + m\,t^1}{M + m}\right]\frac{M\,m}{d^2}$, where t and t^1 were the temperature increments for M and m. When M was very great compared to m, this reduced to $f = g\,\frac{M\,m}{d^2}\,(1 + a\,t)$. Assuming this effect to be linear —it might not be, a time factor coming in—Dr. Shaw found $a = (1.2 \pm 0.05)\ 10^{-5}$ per deg. C. This was a large effect; it would mean that gravitation increased by 1/500 when the temperature rose from 15 to 215 deg. C.

After publishing his first results,* Dr. Shaw continued, it had been suggested that convection currents or a differential radiation pressure might push the silver balls inward, and that the lead balls might also be moved towards one another; a displacement by 0.15 mm. would have explained the results observed. Dr. Shaw and Mr. Hayes therefore installed an electric micrometer to measure the distance apart of the M balls when hot and when cold; they found that they did not move inward, but away from one another when hot, and allowing for this movement the final value for a was $(1.4 \pm 0.05)\ 10^{-5}$. An enormous amount of work remained to be done, and when the price of copper was more reasonable, Dr. Shaw hoped to work with copper balls, which would bear 500 deg., and again to raise the temperature of the whole system, M, m, and the air between.

Professor R. A. Sampson, Astronomer Royal for Scotland, commenting on the gravitation experiments, remarked that an almost false impression seemed to have grown up as to the ability of astronomers to distinguish between right and wrong in such theories. The question whether comets should get hotter and therefore accelerated when near the sun did not receive any conclusive answer by Dr. Shaw's experiments. As regards the suggestion made elsewhere that the small eccentricities of the planets' orbits should change with, or be due to, the solar heat, Professor Sampson had calculated that the eccentricities were already greater than the Shaw effect would make them. Dr. Shaw's first formula had only considered a temperature effect on the large mass, not on the small mass; his second formula was fully symmetrical, as it should be. Professor Whitehead, in the chair, wished to adjourn the discussion—questions were put—since old conceptions, current 40 years ago, were now adrift; but there was no time for further discussion.

(To be continued.)

* Philosophical Transactions, vol. ccxvi., pages 349 to 392; May, 1916.

MACHINES FOR BREAKING AND PUNCHING RAILS.

The illustration on page 298 shows a rail breaker with an open throat. It is found very much more preferable to do this work in an open-throat machine rather than in a closed machine similar to a guillotine shear frame. Owing to the heavy shock, special attention has been paid, in the machine illustrated, to the size of the main bearings for the eccentric shaft, and the eccentric shaft bearing in the cover has been made exceptionally large. Heavy lugs are provided at the top of the frame to ensure keeping this bearing in perfect alignment.

These machines are preferably belt-driven, as careless operators frequently allow the plunger head to jam to such an extent that the machine is instantly stopped, and it is impossible to make the remainder of the stroke without breaking some part of the machine. The belt therefore safeguards this careless operation. If motor-driven, the makers, the Covington Machine Company, of Covington, Virginia, U.S.A., recommend some form of friction drive, although they consider a belt drive the safest. On the plunger is mounted a steel head, and on the lower portion of the jaw are two renewable bearing parallels mounted in a cast steel block pivoted to the lower face of the machine jaw. It has been found from long experience that these bearing parallels wear out quite rapidly, and, where they are mounted directly on the jaw or main casting, that they gradually break down the corners and surface to which they are fastened. The steel block is therefore used to save the main frame from gradual deterioration at this point. The rail, when of the flat-footed type, is preferably broken by laying it with the side of the bulb and thin edge of the flange on the parallels, and a steel fuller on the end of a metal handle is interposed by the operator between the rail and the plunger head. One stroke of the plunger is all that is necessary to break the rail. This particular machine is designed to deal with rails up to and including 100 lb. per yard. Machines are built, however, to deal with any sized rail desired. In this machine the main eccentric bearings are bushed with easily renewable bearings, but the drive shaft is of babbitt construction, with caps and bolts.

The rail punch illustrated on page 299 is a special form of a vertical type punch, also constructed by the Covington Machine Company. The clamping features and arrangement of the punches and stops are specially designed for speed. Referring to Fig. 3, the centre block is a stop; the punch is shown set up with four punches, two for each end of each rail, two rail ends being dealt with simultaneously. This machine is large enough and heavy enough, however, to carry three punches for each end of each rail. The die blocks are made of proper size and shape to fit in between the rails for punching. The arrangement of the clamp or hold-down will be obvious from examination of both the photographs. The cross-shaft is mounted in bearings and attached to the frame back in the throat, and the balance weights are keyed to this same shaft. The two clamping arms are each provided with an extended lug dropped down between the flange and the head of the rail. The actual clamping is done from a cam mounted on the main eccentric shaft outside, engaging with a roller, which roller mechanism is in turn connected with a lever arm on the outer rock shaft for transmitting the motion to the two arms (all three of which are on a key-way or spline), engaging through the spring connections with the clamp arms. The cam is timed so that the clamp affords ample opportunity for sliding the rails into position for punching before they are gripped. These clamping arms can be adjusted to any desired point near the end of each rail.

The machine is, as we have stated, designed to punch opposite ends of two rails simultaneously, which makes it equivalent to punching both ends of one rail in a single operation.

This particular machine is belt-driven, but can be motor-driven when desired. It was designed for lighter-weight flat-footed rails up to and including 40 lb. per yard. The eccentric shaft bearings and also the drive shaft bearings are bushed in a form that is easily removed, the machine being thoroughly built in a high-class manner throughout.

Long-Distance Telegraphy and Telephony.—Professor J. A. Fleming, M.A., D.Sc., F.R.S., will deliver, at University College, Gower-street, W.C., on Wednesday, October 18, at 5.30 p.m., a public lecture on "Long-Distance Telegraphy and Telephony," and a course of six lectures on "Long-Distance Telephony" on Fridays, at 5 p.m., beginning October 27, 1916. The public lecture is open without fee or ticket. The course is open both to members and non-members of the University. Fee, 1*l.* 11*s.* 6*d.* Application for tickets of admission to it should be made to Walter W. Seton, M.A., D.Lit., Secretary, University College, Gower-street, W.C.

INDUSTRIAL NOTES.

SEVERAL Scottish arbitration cases were decided last week by Sir George Askwith, Chief Industrial Commissioner. One was with reference to an application for an increase in wages made to the Scottish Steel Founders' Wages Association by the British Steel Smelters' Association and the Amalgamated Society of Steel and Iron Workers, on behalf of foundry labourers, cranemen, sawmen, boiler firemen and enginemen who, from the beginning of the first full pay following the date of the award, receive an advance of ¾*d.* per hour, or 6*d.* per day, the advance being regarded as war wages. The finding in regard to claims made by the patternmakers, blacksmiths, boilermakers, brass-finishers and other trades in the Clyde district is that as from the beginning of the first full pay following August 4 in the case of engineering establishments, and as from the beginning of the first full pay following August 23 in the case of shipbuilding establishments, the time rates of wages of the men concerned shall be advanced ¾*d.* per hour or 3*s.* 4*d.* per week (according to the custom of the shops), the advance to be regarded as war wages and recognised as due to and dependent on the existence of the abnormal conditions now prevailing in consequence of the war. The advance now awarded is to be paid to time workers only, and is not intended to apply to or affect piece prices. The Kilmarnock boilermakers, and also the iron-founders (Iron and Steel Founders' Federation, Scotland), receive an advance of ¾*d.* per hour, or 3*s.* per week, under similar conditions. With reference to a claim made by the operatives of Messrs. Nobel's Explosives Company, the company having during this year raised wages by 11*s.* a week in three departments and by 18*s.* a week in another department, it was found that the demand for a further advance had not been established.

The heavy rise in the prices of provisions has naturally directed attention to the various causes which have tended to bring about this serious result of the war. As there has been no increase in railway rates since the war began—a 4 per cent. rise, specially sanctioned by Parliament to meet the cost of improved labour conditions granted by the companies in 1911 and 1912, came into force in July, 1913—the railway companies cannot be made responsible for any of the advance in prices. In a pamphlet issued by *The Railway News* examples are given to show how small a part railway rates form in the prices of provisions even at normal quotations. It is interesting to put these examples on record.

For hauling a loaded churn of milk 90 miles and the return of the empty 90 miles, the railways receive 1.04*d.* per gallon, or ¼*d.* per quart. The price of milk at present is at least 5*d.* per quart.

The railway rate to London from Grimsby works out at ¼*d.* per lb. for high-class fish, and 0.16*d.* per lb. for commoner fish at owner's risk. From Aberdeen the figures are 0.62*d.* and 0.40*d.*, and from Penzance 0.42*d.* and 0.32*d.* per lb. respectively.

For foreign meat the rate from Liverpool to London works out at 0.14*d.*, and for British meat from Aberdeen to London at 0.38*d.* per lb.

From Lincolnshire to London the average rate for potatoes is about 9*s.* per ton (2,240 lb.), representing about 9 per cent. if the selling price is £5 per ton; about 4½ per cent., if 10*l.*; and about 3 per cent., at 15*l.* per ton.

For fruit conveyed by passenger train, the rate at company's risk over an average distance of 50 miles is less than one-fifth of 1*d.* per lb., and at the owner's risk one-sixth of 1*d.* per lb. The bulk of the traffic is carried at owner's risk. Similarly, fruit and vegetables are conveyed by goods train at an average cost, including delivery into London markets, of one-fourteenth of 1*d.* per lb. Returned empties, which only load 8 cwt. per wagon, give an average charge of one-eighteenth of 1*d.* per lb. This makes the total cost for full and empty packages one-eighth of 1*d.* per lb.

Strawberries from Hampshire are carried by special trains to London (77 miles) at a sixth of 1*d.*, to Manchester (230 miles) at ½*d.*, and Inverness (600 miles) at ¾*d.* per lb.

The Great Eastern Railway Company carry farm and market garden produce from the grower direct to consumers by passenger train from all the company's stations to London and stations in Great Eastern suburban district, and from all Great Eastern stations (except those within 20 miles of London) to the principal resorts served by the Great Eastern Railway, at a charge of 4d. for 20 lb. This is for special fast deliveries by passenger train; particulars are also given of the ordinary rates for farmers and others, and these are much lower.

A case was recently mentioned in which 2,560 lb. of apples were sent from a western county to Manchester, a distance of 200 miles, and the charge for receiving and loading the fruit, unloading it, and conveying to the market was 0.11*d.* per lb. Assuming that the retail price was only 1*d.* per lb., the figures work out as follow:—

	For 2650 lb. £	*s.*	*d.*	Per lb. *d.*
The grower received ...	0	15	6	or 0.072
The picker received ...	0	13	3	or 0.062
The railway company received	1	3	5	or 0.110
The market and commission agent received	0	7	10	or 0.037
The retailer received ...	7	13	4	or 0.719
	10	13	4	or 1.00

Speaking at Wakefield a few days ago, Mr. J. H. Thomas, M.P., Assistant Secretary of the National Union of Railwaymen, stated that the settlement of the railwaymen's claim for an advance in wages (see page 277 *ante*) should not be interpreted by the public as having had any connection with an attempt to break existing agreements. The question at issue, he added, was never approached from that standpoint; it was based upon circumstances for which neither side was responsible, and was readily and frankly considered in that spirit by the railway companies. He emphasised this by stating further that it would be wrong to assume that in the recent conferences with the railway managers the men's representatives were meeting sharks who were only anxious to take the fullest advantage of their employees. On the contrary, they met a body of gentlemen, who fought their own case fairly and squarely, but who, nevertheless, never failed to see the men's side of the case. He wished to lay stress upon the desirability of preserving that spirit, which was in itself the greatest possible guarantee for peaceful relations in the future.

The following is taken from the circular recently issued by the Federation of British Industries and signed by Mr. F. Dudley Docker, C.B., President:—

The Federation is intended to occupy itself mainly with the broader questions which affect the trade and industry of the country, and to represent British producers and manufacturers in much the same manner that the General Federation of Trade Unions represents organised labour.

The Federation will not interfere with the normal functions of existing trade associations, but will support and strengthen them by every means in its power, in order that they may deal effectively with the particular problems confronting each individual trade.

The objects of the Federation may be summed up briefly as the organisation and development of industry now and after the war, in co-operation with labour and in conjunction with the Government and Government departments.

Among the immediate objects of the Federation will be reconstruction of British trade after the war, development of sources of supply of raw materials, and consideration of questions arising out of the transition from war to peace, such as demobilisation, the future of temporary war workers, measures to mitigate possible unemployment during the transition period, and economic problems in general.

At the same time there will be no delay in dealing with such important questions as the efficient representation of British manufacturers abroad, the improvement of the existing commercial intelligence system, the extension of financial facilities for industry and foreign trade, and the better co-ordination and regulation of freight and transport.

Every effort will be made to ensure that in the future no important action affecting British industry shall be taken by the Government or by Government departments without due weight being given to the views of manufacturers and producers.

The Government of the United States, says *The Iron Age*, is now facing one of the greatest industrial problems it has ever been called upon to solve. A way must be found to secure the speedy construction of 63 warships, the immediate building of which is authorised by the Naval Appropriation Act just signed by the President, and at the same time the newly-created Shipping Board must go into the market to buy or build 50,000,000 dols. worth of merchant vessels. Instead of being able to pick and choose between a score or more of private shipyards eagerly competing for desirable work, the Government now finds itself obliged to appeal to the patriotism of the managers of a few yards, all of which are crowded with work that will keep them busy for 18 months.

Another feature of the present industrial situation which is causing the officials of the Navy Department no little anxiety is the scarcity of skilled labour. The high wages and the exceptional opportunities for the promotion of especially skilled men offered by the munition makers of the country have made heavy drafts upon all the manufacturing establishments of the Government, especially upon the arsenals and navy yards. The private yards have also suffered to some extent, but the greater flexibility of their employment systems as compared with the hard-and-fast rules of the Government yards has enabled them to keep their best men and to develop inexperienced employees for special purposes with great rapidity.

The Minister of Munitions makes the following announcement:—"If a munition worker (as defined by the Munitions of War (Amendment) Act, 1916) is, on or after the 1st day of October, 1916, killed or injured by hostile aircraft, or by the measures taken to combat them, whilst upon the premises of the factory in which he is employed, and if the injured worker or his dependants, on proceeding under the Workmen's Compensation Act, 1916, fail to recover compensation, His Majesty's Government undertake to pay compensation on the scale of the Act."

COLONIAL AND FOREIGN ENGINEERING PROJECTS.

WE give below a few data on several Colonial and foreign engineering projects, taken from the *Board of Trade Journal*. Fuller information on these can be obtained from the Commercial Intelligence Branch, Board of Trade, 73, Basinghall-street, E.C.

South Africa.—The "Official Gazette of the Province of the Cape of Good Hope" publishes a notice of the intention of the council of the municipality of Molteno to borrow the sum of 20,550*l.* for the purpose of carrying into execution a water supply scheme.

Siam.—With reference to the call for tenders by the Siamese Royal Irrigation Department for the supply and delivery of a suction or hydraulic dredger, H.M. Consul-General at Bangkok has forwarded a list of the names of foreign (*i.e.*, non-British) firms which have submitted tenders in this connection. United Kingdom dredger builders interested may consult this list, together with particulars of the prices quoted, at the Commercial Intelligence Branch.

Argentine.—The *Boletin* publishes a Decree approving a project of sanitation and water supply works to be undertaken at the National Tuberculosis Sanatorium at Santa Maria, Province of Córdoba, at an estimated cost of 147,679 pesos currency (about 12,900*l.*). A public call for tenders for the carrying out of the works will be made by the Comisión Asesora de Asilos y Hospitales.

GERMAN PIG-IRON AND THE MANGANESE SUPPLY.—It is stated in *The Iron Age* that complaints of the present quality of German pig-iron are found in a Dutch periodical which says that it is daily proving worse; the opinion is advanced that this deterioration is due to a shortage of skilled workmen and to an insufficient quantity of manganese. The substitute for manganese reported in German papers does not seem to have come up to expectations, continues the report, and the iron is hard and brittle. In this connection we refer our readers to the paragraph on page 225 *ante*, entitled "Manganese Ore at Ilsede"; this latter is of German origin, and our readers will make their own comments.

"BRITISH AND GERMAN INDUSTRIAL CONDITIONS."—There has just been issued a brochure under this title by Mr. Andrew Stewart, M.I.E.E., at 6*d.*, containing a series of articles which appeared in *Electricity* between April 21 and June 2 last. Mr. Stewart brings to bear upon his work as an author an intimate knowledge of German methods, acquired by business association with many firms in that country, as well as sound technical knowledge. Consequently his treatment of the subject possesses practical definiteness, which is not present in many other contributions to the all-absorbing question of the organisation of trade after the war. He does not place much reliance on tariff walls, justifying his view by an examination of the figures of imports and exports to free-trade and protected countries. He is much more inclined to believe that better banking systems, the establishment of cartels, cheaper transport, and, above all, a fuller use of the mechanical means of production in association with better relations between capital and labour, will insure improved prosperity in the future His suggested remedies are: (1) that more specialised education is wanted; (2) that education should be continued, so far as the mass of the people are concerned, beyond the ordinary school age, and that this additional education should not depend solely upon evening classes, as many artisans are not physically capable of profiting by it, and consequently much of the money spent on evening classes is wasted; (3) that financial support for fresh enterprises must be more easily obtained by means of industrial banks or otherwise; (4) that employer and employee should co-operate in the trade war, as they have in the fighting line and the munition factory; (5) inland transport to be reorganised, co-ordinated and brought up to date. He considers that the success of the Ministry of Munitions should result in a reconstitution of that organisation as a department of industry and commerce under a Minister of Commerce, with Cabinet rank. It is desirable to have an organisation to support industries, especially new ones and essential or key industries, which cannot stand the blast of competition without State aid, which might take the form of the Government grant of a subsidy or the guarantee by the State of a certain interest on the money sunk in new industries or in helping old ones to weather a period of serious competition.

STENCIL-CUTTING MACHINES.

WE gave on page 114 of our last volume a short illustrated description of the "Diagraph" stencil-cutting machines which are sold in this country by Messrs. Herbert E. Williams and Co., 47, Lime Street, E.C. A new type of these machines has now been brought out. It is completely enclosed in a strong metal casing; this covers the important working parts of the machine and protects them from the dust and damp sometimes found in the packing and despatch departments of factories where they are generally used. The new dial is stationary and the pointer which indicates the letter to be cut is instantly brought into position by means of a new wheel provided for this purpose on the top of the machine. The operating lever is now horizontal and the bedplate has no arms or obstructions, so that the Diagraph which cuts stencils to any length required can be manipulated by any boy or girl. Its labour-saving qualities must, therefore, be even greater than in the older model. Messrs. Williams inform us that these machines are largely used for marking cases despatched to the various fronts.

LIQUID COMPASS.

THIS war has given a great impetus to the manufacture of liquid compasses, because they are very much more nearly dead beat than the compass in which the card is carried solely on a pivot. In the liquid compass the weight of the card and of the magnet is very largely borne by the liquid, so that the friction on the pivot is reduced to a very small amount, the pivot being then solely for the purpose of guiding the card. The liquid, by its viscosity, quickly damps out the vibrations when the compass is turned from one point to another. The liquid itself is a mixture of spirit and glycerine of such proportions that its viscosity allows the card to rotate fairly easily, but at the same time damps out its motion in a very short time.

Liquid compasses are by no means a novelty, although they have not hitherto been very largely used as pocket instruments. Indeed, one of the earliest compasses, that invented by Petrius Peregrinus, and described by him in the year 1269, was provided with a liquid upon which the card floated; and, of course, everyone knows the old experiment of floating a magnetised sewing needle upon water, and allowing it to set itself due north and south. Ship compasses have also been liquid borne for a great number of years. On this page we illustrate a new form of liquid compass which has been got out by Messrs. S. Smith and Sons, Limited, of the Grand Hotel Buildings, Strand, London. It will be seen that this is not one of the prism type compasses, the reading being observed through a small lens shown at the right hand side. This lens is hinged, and can be moved slightly backwards or forwards in order to bring the figuring on the compass well into focus. The cap of the compass, which is shown raised, has in it a disc of glass on which is ruled a fiducial line, which is brought by the observer on to the point to be observed before he reads the figure on the compass itself. This reading gives the number of degrees by which the line drawn from the compass to the object subtends a line drawn to the magnetic pole. Of course, all compasses are directed to the magnetic north, which here now varies by some 15 degrees from the axial north of the earth. It is not possible to correct them for this divergence, because the divergence itself is different in different parts of the world, and a compass which was true in London would not point truly in the West of England or, say, in Mesopotamia. In working from a map, it is, of course, necessary to know the divergence of the magnetic pole from the north at the particular spot on which the observer stands.

One of the purposes of a military compass is to enable marches to be made from indications already taken from the map. The course is laid out to some prominent object on a certain bearing; when that object is attained a second bearing directs the course to another object, and so on. It is possible to carry out such a march at night if the objects in question are such as can be readily recognised in the dim light.

The compass itself is provided with luminous marks, to enable it to be used after dark. The arrow in the centre can always be seen pointing to the north. Around the compass is a ring divided up into degrees, and inside this ring is a second, carrying a fiducial mark, and this second ring can be rotated in either direction to bring this fiducial mark opposite any given angle. When once set like this it is easy to use the compass in the dark. Further, at each 90 degrees there are two light spots on the dividing ring, and there are also other spots at distances of 20 degrees apart. As 90 degrees will not divide by 20 without a remainder, the intervals at each side of the north and south poles are 10 degrees, and these short intervals serve to identify these particular points in the dark. Diametrically opposite the fiducial mark on the inner movable ring is a round dot which is useful for a return march when the outward march has been made by bearings. It is naturally a little difficult to set out the return route without making any mistakes. First, the correction for the magnetic deviation has to be made, and then each of the other directions has to be reversed. The

use of this dot does the whole matter automatically, and it is possible by the use of this dot to turn round and retrace the steps already made without any chance of error. These compasses can be obtained with certificates from Kew, guaranteeing that the maximum error at any part shall not exceed half a degree.

BOILERS FIRED WITH POWDERED COAL.—What is believed to be the first large installation of pulverised coal burning under a complete battery of stationary steam boilers, says *The Iron Age*, has been in operation since August 1 at the shops of the Missouri, Kansas and Texas Railroad at Parsons, Kansas. There are eight 250 h.p. O'Brien water-tubes, and an evaporation of 10.7 lb. of water from and at 212 deg. F. per lb. of fuel was obtained with 16 per cent. of carbon dioxide in the stacks. The plant was designed and put down by the Fuller Engineering Company, Allentown, Pa.

DIRECTORY AND CHRONICLE FOR CHINA, JAPAN, &C.—This directory, which covers China, Japan, Corea, Indo-China, Straits Settlements, Malay States, Siam, Netherlands India, Borneo, the Philippines, &c., for 1916, is the 54th annual edition. It is issued at the price of 30*s.* net by the Hong Kong Daily Press, Limited, 131, Fleet-street, E.C. It contains a number of excellent maps and plans of towns and close upon 1,800 pages of printed matter. This includes interesting general information on the principal countries and districts dealt with; data which appeal to commercial firms; directories of the industrial and commercial enterprises, of the consulates of the various countries, of the foreign residents, &c. Information is also given concerning agreements, conventions, rules and regulations which govern the intercourse with the countries covered by the directory. The book, like the former editions, will prove useful to all firms having dealings with the Far East.

PROPOSED DEPARTMENT OF MINERALS AND METALS.—The Councils of the Iron and Steel Institute, the Institute of Metals, the Institution of Mining Engineers, and the Institution of Mining and Metallurgy have addressed a communication to the Committee of the Privy Council for Scientific and Industrial Research, pointing out the necessity of measures being taken to provide the necessary machinery for the protection and advancement of the economic welfare of the mineral and metal industries of the Empire. In this it is pointed out that various departments of the Home Government, such as the Geological Surveys and Museum of Practical Geology, the Board of Trade, the Home Office, the Imperial Institute, and, since the outbreak of the present war, the Foreign Office, the Admiralty, the War Office, and the Ministry of Munitions, have all been concerned with the collection of information bearing on the sources of supply of minerals and the production of metals. There does not appear, however, to have been any serious attempt to co-ordinate and render available even such information as has been collected by these departments, and considerable overlapping and duplication of effort, with corresponding waste and confusion, must have occurred. It is therefore suggested that there should be organised a central department of minerals and metals to deal with mineral surveys of the United Kingdom, the Crown Colonies and other British Possessions; and also to undertake the systematic collection and co-ordination of information bearing on the occurrence, uses and economic value of minerals and their products. The body would further undertake the investigation of all questions and problems relating to the mineral and metallurgical resources of the Empire, and would publish accounts of the developed and undeveloped mineral resources and the position of each mineral or metal. This application was dated September 22, and no doubt is under consideration.

GERMANY AND ROUMANIAN PETROLEUM.

THE production of petroleum in Roumania has decreased materially during the war, the figures for the three years 1913–15 being 1,890,000 tons, 1,770,000 tons, and 1,670,000 tons. The export trade in the products which were allowed to be exported has, on the whole, been done at very remunerative figures, but the export has receded considerably in the matter of quantity. The aggregate export of petroleum and by-products was, for the three years, 1,036,444 tons, 684,024 tons, and 429,087 tons. The exports to Germany and Austria-Hungary were :—

	Germany.	Austria-Hungary.
1913	126,295 tons.	77,184 tons.
1914	99,165 ,,	84,253 ,,
1915	154,688 ,,	225,699 ,,

To England, France and Italy no export whatever took place during last year, and the export to Russia only amounted to 578 tons.

Germany is much interested in the Roumanian industry, in which it has invested much capital and skill during the last 20 years. Of late years, the Roumanian Government and capitalists have been endeavouring to nationalise this important industry, and of the 4,400,000*l.* of assets shown in the balance sheet of the Steaua Romana at the end of last year, between 2,400,000*l.* and 2,000,000*l.*, certainly lay in Roumania, 1,720,000*l.* representing installations, 360,000*l.* oilfields, and the balance means of transport and stock. The 1,720,000*l.* of assets and debtors were probably outside Roumania. It remains to be seen how these two sections—the Roumanian and the one outside Roumania—will be able to work during the war. A substantial sum out of the profits for the first seven months of the present year is, no doubt, available for the Board. The last business year (7½ months), after writing off 260,000*l.*, yielded 200,000*l.* for dividend—equal to 10 per cent. on the share capital.

As regards the German Petroleum Company, the position seems more favourable. At the end of 1915 the Roumanian portion of the shares amounted to 6,820,000 marks, besides 2,170,000 marks of other Roumanian items, and in addition to advances to Roumanian affiliated concerns. As regards the latter, the Vega Refinery Company and the Petroliter Transport Company, however, are said to be creditors of and not debtors to the German Petroleum Company, and the Concordia concern has, of late years, been able to reduce its liabilities.

The trade with Roumania in petroleum products has been of importance as regards lubricating oils, petroleum for lighting and gas oil, whilst the export of petrol to Germany and Austria has been very limited. Lately, permission for export of petrol was certainly granted, but there were several obstacles in the way. It is claimed for Germany that the stoppage of the Roumanian supplies will cause no trouble. What is called the statistical position as regards lighting oil, fuel and petrol is secure for a long time to come. Besides, Galicia delivers promptly the quantities contracted for, and although the recently-opened oil traffic on the Danube, *via* Orsova, has again been stopped, it is stated that this does not matter much.

PERSONAL.—Mr. George Ellison, of Queen Anne's Chambers, Westminster, has removed his Yorkshire Branch Office from Sheffield to Standard Buildings, City-square, Leeds.

AMERICAN LOCOMOTIVE COMPANY.—For the first time for the last eight years the American Locomotive Company has authorised the payment of a dividend upon its common stock. The dividend is, however, not very large—only 1¼ per cent.

COLLEGE COURSES.—The courses at Northampton Polytechnic Institute, Clerkenwell, include day and evening courses in Engineering (Civil, Mechanical and Electrical), in Technical Optics and in Horology. The engineering courses include sub-sections in Automobile Work, Aeronautics and Radio-Telegraphy. In addition there are evening courses in Electro-Chemistry, Metallurgy and Domestic Economy. A "Glass-Workers'" evening course is being jointly undertaken by the Technical Optics and the Technical Chemistry Departments. The classes in Submarine Cable Work are being continued, and elementary and advanced classes in Radio-Telegraphy are also being announced. The classes for the day courses commence on Monday, October 2, and those of the evening courses began on Monday, September 25. Enrolments for the latter are now in progress.

COMPETITIVE EXPORTS.—It is satisfactory to note that in 1915 the percentage proportion of the United Kingdom in competitive exports of machinery to Australia never stood higher. The British proportion was 63.61 per cent. in 1909, 63.43 per cent. in 1910, 61.45 per cent. in 1911, 62.58 per cent. in 1912, 63.20 per cent. in 1913, 61.90 per cent. in 1914, and 64.90 per cent. in 1915. The American share came out as follows in the analysis :—1909, 10.23 per cent.; 1910, 10.59 per cent.; 1911, 11.54 per cent.; 1912, 11.76 per cent.; 1913, 11.80 per cent.; 1914, 11.90 per cent.; and 1915, 15.20 per cent. The American share of the exports of motor car chassis has shown a tendency to increase of late. The imports of competitive merchandise into Australia from all sources has represented the following yearly values during the period under review :—1909, 40,417,636*l.*; 1910, 47,145,514*l.*; 1911, 52,295,529*l.*; 1912, 61,230,761*l.*; 1913, 60,551,516*l.*; 1914, 31,256,148*l.*; and 1915, 48,867,011*l.*

NOTES ON THE EFFECT OF BLAST-FURNACE GASES ON WROUGHT IRON.*

By DR. J. E. STEAD, F.R.S., Vice-President.

MR. T. H. BYROM, in his paper on "The Carburisation of Iron at Low Temperatures in Blast-furnace Gases,"† showed that soft steel, when exposed to the action of the gases from blast-furnaces at the Wigan Furnaces, which were employed in the manufacture of ferro-manganese, is substantially converted into carbide of iron, Fe_3C, without the formation of any free carbon in the interior of the mass.

The temperature of the gases varied between 600 deg. and 700 deg. C.

Sir Lowthian Bell, previous to 1872, showed that when carbonic oxide is passed over iron oxide at 400 deg. C. and above, reduction of the oxide to the metallic state is more or less complete, and coincidentally the carbonic oxide is reduced to free carbon in the spongy mass.

John Pattinson,‡ previous to 1876, working in conjunction with Mr. Charles Wood, proved that fire-bricks, used in furnace linings, if they contained free oxides of iron, disintegrated in course of time, due to the same peculiar reaction. The carbonic oxide, penetrating the porous bricks, attacked the oxide and deposited carbon, which, exerting enormous pressure, burst the bricks into pieces.

Pattinson also recorded the results of an examination of a black powder found in the concrete of a gas-flue at the Tees Ironworks.

It contained the following :—

	Per cent.
Carbon	91.76
Iron	3.54
Phosphorus	0.043
Silica oxygen	1.777
Loss on drying at 212 deg. F. ...	2.880
	100.000

Ratio of iron to carbon $\frac{91.76}{3.54} = \frac{25 \text{ carbon}}{1 \text{ iron}}$

Pieces of cast iron, having all the properties of Cleveland pig-iron, were found inside the mass of black deposit.

In the incombustible part of the black substance, excluding the oxygen, the elements were found to be associated in the same ratio as they exist in Cleveland pig-iron. It was assumed that rusted pieces of Cleveland scrap iron had accidentally got into the concrete, that the carbonic oxide had attacked the rust, and the spongy iron produced had induced the continuous deposition of carbon from the carbon oxide.

The exact reactions which actually occur are far from being clear, and it is doubtful whether they can be dismissed by the formula usually advanced.

The question as to whether the lower oxides of iron play any part in the reaction is not clear.

It is known that during the carburisation of iron in the cementation process, the carbonic oxide gas is the vehicle of the carbon and that carbon dioxide and iron carbide are the products :

$$Fe_3 + (CO)n = Fe_3C + (CO_2)n + (CO)n,$$

and that it is improbable that oxides of iron play any part as an intermediary.

Much might be written on the alleged chemical and catalytic reactions, but it is not proposed to do this at present, the object being to show that apparently the oxides imprisoned in wrought iron induce carbon precipitation, and the partial disintegration of the iron itself, when such iron is heated in blast-furnace gases rich in carbonic oxide. It has been shown that at 550 deg. C. and above, gases containing about 30 per cent. carbonic oxide and 3 to 4 per cent. carbonic acid rapidly carburise iron, but at lower temperatures than 500 deg. C. there is no carburisation.

The object of this note is to describe the effect of blast-furnace gases on wrought iron at temperatures between 400 deg. and 500 deg. C.

The phenomena were observed quite incidentally when experimenting on the magnetic properties of manganese steels with the object of ascertaining the effect of very prolonged heating at relatively low temperatures. Bars of the steels were placed inside of a wrought iron tube or case, and the case with contents was placed in the middle of a gas-flue, where the temperature ranged between 400 deg. and 500 deg. C., and was allowed to remain there for nearly two years. But the case and the bars were removed and examined at intervals.

Fig. 1 clearly shows the method of suspending the case in the gases.

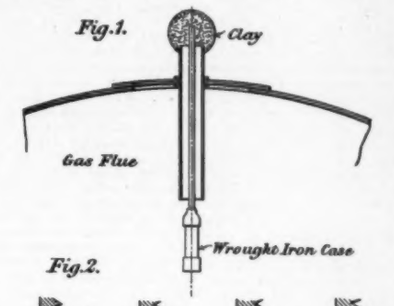
After exposure for a year, the wrought-iron tubes were found to be blistered in many places, and at certain points layers of the iron had been torn away from the places where the screwing terminated and were beginning to curl over in the way illustrated in the sketches (Fig. 2).

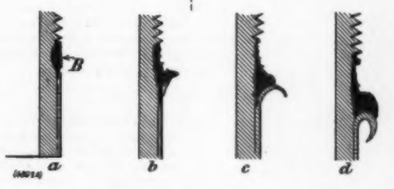
As one had the opportunity of examining the outside of the case at intervals, the gradual and progressive tearing action was followed. From the first it was clear that carbon was being deposited from the gas and was responsible for causing the disruption.

Fig. 2, *a*, *b*, *c*, *d*, show step by step the mechanical effect of the carbon. It is almost certain that that element was continually deposited along the line of cinder, and behaved just as if it were the point of a planing tool. The iron itself was not carburised, as was proved by an analysis which gave only 0.05 per cent. carbon, a fact justifying the conclusion that the temperature had not exceeded about 500 deg. C.

On screwing off the cap to get at the bars, a considerable quantity of fine dense black powder fell out with the bars, and the lower part of the upper tube contained much of the same substance loosely adhering to its sides.

In physical appearance the powder resembled lamp-black. All the blisters on the tubes were filled with this black powder, and some had deposited on the inside walls of the thicker tube as well as the walls of the thin tube. Originally these walls, as well as the exterior surfaces, were coated with a thin layer of blue scale, as is usual with all such hot rolled material. Carbon seems to have deposited over the whole interior surfaces, but none at all on the exterior portions, excepting at the parts which had been cold distorted at the screwed portions beyond the terminations of the caps.





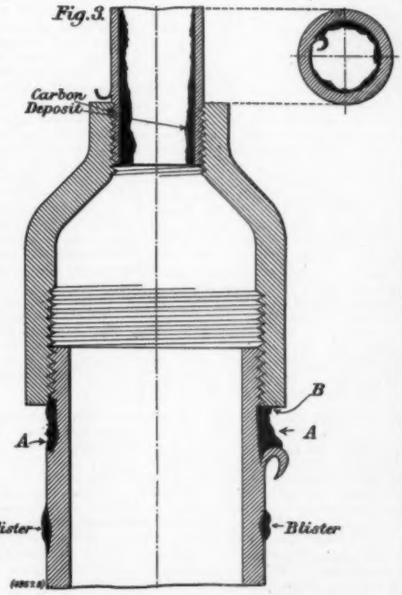


Fig. 3 represents a section through the wrought-iron case and upper tube and the parts marked A where carbon had deposited.

A most remarkable circumstance was noted about the places at A. Parts of the screw-threads had been removed by the disruptive effect of the carbon from the gases. Originally the threads were continuous to the end B, but after two years only the black deposit remained, together with particles of the iron which had been disrupted. A slight coating of black deposit was found on the bars of manganese steel, even on the faces that had been polished. There was not sufficient of the powders to make thorough analyses, but both free iron and magnetic oxide were isolated. The free iron was determined by finding the amount of copper given weights of the powders precipitated, and from that the iron was calculated. Each of the powders on treating with dilute sulphuric acid gave off hydrogen gas. The residue, after dissolving out the free iron, contained carbon and a black substance readily attracted by a magnet, and after this was separated the carbonaceous residue contained non-magnetic oxides equivalent to about 20 per cent. of non-magnetic oxide on the original sample. The partial analyses were as follow :—

	Inside the Case. Per cent.	Inside the Upper Tube. Per cent.
Carbon	27.8	72.60
Free iron	10.9	7.90
Non-magnetic oxide ...	21.0	Iron 13.50
Magnetic oxide	26.0	
Manganese oxide ...	1.3	0.25
Silica	2.9	0.90
Total iron	44.4	21.4

The quantity of powder from the upper tube was not sufficient on which to determine the amount of magnetic and other oxides. The larger amount of manganese in the deposit found in the case itself suggests that a portion of it had come from the surfaces of the manganese steel bars. As the caps were screwed tightly on to the ends of the case, it was supposed the case was quite gastight ; and if it was, one is forced to the tentative conclusion that carbonic oxide passed through the solid iron. That it is capable of penetrating iron to a depth of about ¼ in. at 600 deg. to 650 deg. C. has been proved by previous experiment, but that it should penetrate right through the iron and deposit carbon on the inside walls of the iron tubes at under 500 deg. C., if true, is very remarkable, and further trials are being conducted to confirm or negative these observations.

The explanation offered for the disruptive action on the screwed portion of the tube is that, in the act of making the screw, the enclosed cinder layers and threads were crushed and made very porous to gases, and the CO gas penetrated and burst away the metal above the cinder layers.

On testing the black deposits for carbon by colour, only traces were found in the deposit from the upper tube but 0.21 per cent. in that from the lower tube, but a portion of this may have come from the manganese steels, which contained up to 2 per cent. carbon. Incidentally, it may be remarked that at high temperatures spongy iron reduced from iron ore is rapidly carburised, and it is justifiable to believe that as ore is reduced and descends down the shaft of a blast-furnace it becomes highly carburised before it reaches the melting zone, and not, as is usually assumed, that it remains as spongy iron till it begins to melt. It is more than probable that before the reduced iron is half-way down to the hearth it will have combined with at least 2 per cent. carbon.

In reviewing the result of the observations and experiment given in this note, it would appear :—

1. That even hard and refractory iron scale and the magnetic cinder enclosed in wrought iron are capable of reacting with carbonic oxide at temperatures between 400 deg. and 500 deg. C.

2. That wrought iron containing free oxides is capable of being partially broken up by the action of carbonic oxide gas on the enclosed oxides or cinder.

3. That under the conditions named even initially non-oxidised steel acts on carbonic oxide gas, inducing carbon to be deposited on the surface.

UNITED SERVICES EMPLOYMENT COUNCIL.—This Council has for its objects to find business employment for disabled, invalided, or retired officers and gentlemen who have served in the ranks of His Majesty's forces ; also to find employment for families of gentlemen who have served in the ranks or have fallen on the field of honour, and to assist the inexperienced with funds for purposes of necessary training at various commercial and industrial centres and institutions, in order to qualify them for private, commercial and other positions, and help to supply the shortage of skilled assistants in our trades, industries, offices, &c. The Council appeals to the public for 200,000*l.*, necessary for the training at various commercial and industrial centres and institutions of disabled, invalided and retired officers, gentlemen of education, who have served in the ranks, and the latter's families, in order to prepare them for positions in regard to British overseas trade expansion, the capture of German commerce, and for other remunerative engagements. Cheques can be sent to Mr. Alfred Bentley, Manager, London County and Westminster Bank, Parliament-mansions, Victoria-street, Westminster.

THE GERMAN WIRE INDUSTRY.—The efforts to gather the whole of Germany's wire industry into one combine have lately been resumed on account of the Düsseldorf German Wire Union soon ceasing to exist. It was formed in the year 1913, between some 35 wire-drawing works and five wire-rolling mills. This agreement provided for the mixed concerns supplying the drawing mills with raw material at a fixed base price, both groups, according to a fixed scale, participating in the profits made by the drawing works. During the last few months differences have arisen between the two groups ; the wire-drawing works, on account of the unusual rise in the cost of production, holding out for a larger share of the profits, which the mixed works refused. The combine does not seem to have satisfied either side, and its dissolution was duly notified last May. The factories in question will consequently become free the end of the present year, and exertions are now being made to prevail upon the works in question to join the price convention for wire and wire products, to which the Düsseldorf Union belonged as a closed concern. Two-thirds of the works in question have already acquiesced, and most of them are likely to join ; some small outside works, which have hitherto kept apart from all combines, are also being approached, and there is a chance, therefore, of the entire German wire industry being combined in one convention.

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* Paper taken as read before the Iron and Steel Institute.

† Journal of the Iron and Steel Institute, 1915, No. II., page 106.

‡ *Ibid.*, 1876, page 85.

THE ACCIDENT TO THE NEW QUEBEC BRIDGE.

On September 15 we published an account, as far as it was then possible to do so, of the accident which occurred to the new Quebec Bridge on the previous Monday, September 11. Very few technical details had then been received, but we were able to give an account of the preparations which had been made for lifting the central span, and to suggest the cause of the failure. This week photographs have arrived from America showing the span as it appeared just before the accident and immediately afterwards, but so far no really technical description has been received in this country.

On page 306 we reproduce three of these photographs. Fig. 1 shows the span itself, as it appeared when ready to be floated into position between the two cantilevers. This span was 640 ft. long by 88 ft. broad, and, as will be seen, it was a structure of apparently immense strength, being elaborately braced in all directions. Its weight was supposed to be 5,142 tons. Fig. 2 shows the span almost ready to be lifted and Fig. 3 was taken after the bearing under the south-west corner had given way. It will be seen that it is still supported at three corners, but at the fourth corner it is free, and the whole span has twisted through something like 60 deg. On the side nearest to the spectator both the top and bottom booms are perfectly visible, and it will be seen that both of them appear to have failed, the lower boom, curiously, having buckled, and the cross-bracing having given way at several places. At the far side it is only the upper boom which is visible for about half its length; the remainder of it apparently is submerged under the water, which appears to be beaten up into foam by the impact of this vast mass falling into it. These photographs do not carry us very much further as to the real cause of the disaster, but, at any rate, they make it clear that the span was only held up at three corners, and, the fourth corner being free, the whole structure twisted through a large angle and finally broke away and fell to the bottom of the water. We are daily expecting a complete description and drawings from our correspondent in America, and defer any further notice of this matter until they arrive.

STUDENTS IN CAPTIVITY.—From various camps a continuous stream of applications for books for serious study comes to the Committee managing the British Prisoners of War Book Scheme, who express the hope that the public will continue, by offers of suitable books (new or secondhand), to support a war charity the machinery of which is being increasingly taken advantage of. Further particulars can be obtained on application to Mr. A. T. Davies at the Board of Education, Whitehall, London, S.W.

JAPAN AS A SOURCE FOR TUNGSTEN.—We read in *The Iron Age* that exports of tungsten ore from Japan in 1915 were 85 tons to the United States, 214 tons to France and 110 tons to the United Kingdom, or 409 tons in all. Estimated shipments to July 20, 1916, are placed at 480 tons, most of it going to the United States. The tungsten output of Japan is reported as 25 to 40 tons of ore per month from the Kiwada mine, 10 to 11 from the Takitori mine and 75 from several small mines. Those in Corea produce between 50 and 60 tons per month. Attempts were made to obtain tungsten from Siam, but the ore contained large percentages of tin, greatly reducing the value.

THE PROBLEM OF THE SHIPPING ON THE DANUBE.—The Danube conference, held in Budapest in the beginning of September, and comprising German, Austrian and Hungarian delegates, has again drawn attention to this difficult problem. That the possibilities of the Danube have not been adequately exploited will appear from the fact that the aggregate traffic on the Danube, with its length of 2,500 km., barely amounts to 15,000,000 tons, whilst the traffic on the Rhine, over a course of only 570 km., in the year 1913 exceeded 104,000,000 tons. The cost of the regulation of the Danube up to the end of 1915 amounted, in Bavaria, to 25,000,000 Austrian kroner, in Austria to 171,000,000 kroner, and in Hungary to 250,000,000 kroner. The cost of a 2-m. regulation would entail a calculated expenditure in Bavaria, from Ulm to Parrau, of 233,000,000 kroner, and in Hungary of 66,000,000 kroner; what the cost of passing the falls in Austria and of the works necessary at the delta would be has not yet been ascertained. The European Danube Commission, with domicile in Galatz, has, from 1857 to 1911, expended some 55,000,000 francs on the mouth of the Danube, preparatory work, shipyards at Tultscha, &c., 37,000,000 cub. m. dredging having been done, 1,000,000 cub. m. used, &c. Thanks to these labours the ship canal now proceeds in an almost straight line from the Black Sea, with a depth of about 20 ft. as far as Sulina, where the depth in the year 1856 only amounted to 8 ft., so that the capacity of vessels able to enter the Sulina area has been raised from 500 tons to 4,000 tons. It will appear from these figures that it would entail an immense expenditure to create the much-desired Central European waterway, deep enough to enable 1,000-ton vessels to proceed from the North Sea or the Baltic into the Black Sea without reloading.

NOTES FROM THE UNITED STATES.

PHILADELPHIA, September 13.

REPRESENTATIVES of the Allied Nations have been scouring the market for opportunities to place orders for shell, steel and other products; the contracts recently placed are estimated approximately at 100,000 tons. The Steel Corporation on September 1 had on its order books 9,660,350 tons of orders. Much new business is being offered. Bessemer and open-hearth steel are in very urgent demand. Russia has closed an order this week for 4,000 cars. The same Government is in the market for a large tonnage of rails, The demand for structural material which recently developed still continues—upwards of 50,000 tons of shapes will be arranged for this week. A shortage of ore supply is threatened this winter; even during the summer months the entire production is absorbed. Lake shipments this season, 39,215,000 tons. Lake freights have advanced. The blast-furnace industry is turning out pig-iron at the rate of 38,150,000 tons a year. During the past week 60,000 tons of billet steel were sold for export. Semi-finished steel is becoming scarcer. Sheet-makers are unable to meet current inquiries satisfactorily. The tin-plate mills are urged to book business for next year's delivery. Mills everywhere are driven to the limit of capacity. Pennsylvania mills have been obliged to refuse orders for 45,000 tons of shell bars, and also 20,000 tons of ship-plates for Japan and Italy. Domestic manufacturers are pressing hard for deliveries. Railroads are having more difficulty in placing orders for track supplies after July, 1917. Large extension of steel-making capacity continues to be undertaken. The general impression in steel trade circles is that the pressure for material of all kinds will continue unabated, and that under the increasing capacity now being rapidly developed means will be found to meet the increasing demand, which at present seems beyond the ability of the country to meet it. The country has been surprised at its ability to take care of domestic and foreign demand, and there is no doubt that enterprise will be sufficient to meet the great bulk of requirements which will be presented to it during the coming year.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

South Yorkshire Coal.—There are very heavy inquiries for all classes of house coal, and the better qualities are wanted both for the home and the country trade. Good tonnage is available, but there are no surpluses to place to stocks. For the inferior classes in this section the inquiry is on a large scale in view of the great demands for gas-making purposes both at home and abroad. For France and Italy fully 25*s.* is offered at pit for gas-making fuel, and collieries are eager to do business at this remunerative figure. A firm tone characterises the market for manufacturing fuels. Works, railways, and other large industrial undertakings are asking for maximum deliveries, and the total output of the collieries is absorbed from day to day. As has been stated at a number of company meetings recently held, there is a good deal of slack working on the part of South Yorkshire miners, and this limits the quantity of coal placed on the market. There is a none too plentiful supply of best steam hards, and works are gratified when they secure sufficient to meet their daily requirements. Cobbles, nuts, and slacks are freely sought. Cokes of all descriptions maintain their customary strong position. Quotations:—Best branch hand-picked, 20*s.* 6*d.* to 21*s.* 6*d.*; Barnsley best Silkstone, 17*s.* 6*d.* to 18*s.* 6*d.*; Derbyshire best brights, 17*s.* 6*d.* to 18*s.* 6*d.*; Derbyshire house coal, 16*s.* to 17*s.*; best large nuts, 15*s.* 6*d.* to 16*s.* 6*d.*; small nuts, 15*s.* to 16*s.*; Yorkshire hards, 16*s.* 6*d.* to 17*s.* 6*d.*; Derbyshire hards, 16*s.* to 17*s.*; best slacks, 12*s.* to 13*s.*; seconds, 10*s.* 6*d.* to 11*s.* 6*d.*; and smalls, 8*s.* to 9*s.* per ton at pit.

Iron and Steel.—Sheffield industries are, with only minor exceptions, continuing to work at the maximum pressure, though this week-end will mark a notable change. Commencing Thursday evening, the munition workers will enter upon their long-postponed holidays, and they will be released from the toil of the shops until the following Tuesday morning. The privately conveyed opinion of the authorities to the heads of the large firms is that the workers have well earned their respite. There are no outward signs of any striking trade developments, and works managements are well content to enjoy the present period of smooth working so long as the full output is maintained. A revival in the foundry iron business is reported from certain districts in South Yorkshire, but it has not spread to this city, for here the market is featureless. Few, if any, large contracts are being placed, and the great proportion of the trade that is done is with the heavy foundries and the engineering shops. Satisfaction is felt at the consistent regularity with which the supplies of hematites continue to arrive. Deliveries now more nearly approximate to local requirements than they have ever done since the outbreak of war, though there is as yet little opportunity for works to lay in stocks. Basic steel is dear and scarce. Billets cannot be had in sufficient quantities, and the few American deliveries which have arrived are so much below the standard of the home productions that they cannot be worked except at a sacrifice. No reliance is placed on the Swedish sources of basic steel, and the tonnage received is now a negligible amount. Wire-workers are fully employed, but the expected has happened in the stove grate trade, and the workmen both in Sheffield and in Rotherham are on short time. Yet the workmen have an application before the Committee on Production for a substantial increase in wages. The light casting trade is also experiencing a period of slackness, due in a large measure to the almost total suspension of the ordinary building trade. Cutlery manufacturers have more orders than they can cope with, but they have to release more men for the army. Swordmakers are finding the demand falling off in consequence of the reduction by the War Office of their requirements by two-thirds. All other Government work has an increasing tendency. Recent contracts are for knives, forks, clasp knives, tools, bill and reaping hooks, railway plant, railway wagons and parts, boilers and fittings, and iron and steel. The severer application of the restrictions governing the overseas business increases the difficulties confronting manufacturers, but they still make headway. Indents have been received for files, saws, sheep shears, pruning hooks, tools, steel, springs, and electro and silver plate.

Yorkshire and Other Trade Matters.—Some important observations were made at the annual meeting at Sheffield on Monday of the Sheepbridge Coal and Iron Company, Limited, of Chesterfield. The chairman, Mr. Frederick Fowler, stated that the net profit for the year was 205,891*l.* 1*s.* 1*d.* which, with the balance of 44,069*l.* 12*s.* brought forward, made 249,960*l.* 13*s.* 1*d.* to dispose of. The dividend at the rate of 15 per cent. was very gratifying. Despite these satisfactory figures, a decreased output had to be recorded, mainly owing to 2,600 miners having joined the colours. Large supplies of coal have been sent to France, owing to the German occupation of French coalfields. A serious matter had yet to be faced, and that was the after-war position. It would require a most careful handling for there would be such disturbances in the labour market caused by the effects of the war—the high wages the workmen had been quite properly earning and the high profits colliery companies had been making—that when there was a return to the normal state of things a conciliatory spirit would have to prevail on all sides if disaster was to be averted. If there were strikes and great industrial disturbances it might end in the Germans capturing our trade and not us the German trade. Lord Aberconway regretted there had been a great diminution in output of both coal and iron of fully 20 per cent., due to the number of miners who had entered the army and also to the undesirable habit certain workmen had of "slacking." The wages paid were about the same as last year, which meant that a considerably less turnover had been made by the workmen for the same remuneration. What was required by all was a full and patriotic sense of responsibility, for every falling away from the normal output hampered the progress of the army. As to the future of the trade, that was obscured by the war situation.

John Brown and Co., Limited.—Lord Aberconway, who presided at the annual meeting of Messrs. John Brown and Co., Limited, of Sheffield and Clydebank, which was held in Sheffield on the 26th inst., stated that whilst they could not discuss, during the war, details of their great undertaking, when it could be fully described it would form one of the most remarkable chapters of British industry. Their work at present was practically solely for the army and navy, but when the war was over they anticipated a great demand, which they were prepared to meet, for merchant tonnage. All were working strenuously, except in the collieries, where absenteeism was largely responsible for the increased cost of coal. Colonel Firth denied the existence of the armament ring which was alleged at the meetings of the Engineering Section of the British Association. Nor had armament firms refused to accept outside help as had been stated. The reverse was the case: they had sought it.

AFRICAN COAL ON THE PACIFIC COAST.—According to a German shipping paper, negotiations are pending for starting a regular steamer line after the war between South America and South Africa, proceeding from Iquique. On the outward trip nitrates are expected to form the principal cargo, and coal from South Africa on the return trip.

THE WORLD'S PETROLEUM.—The production of crude petroleum throughout the world last year was 426,892,673 barrels. This beats the record output of 1914 by 28,194,307 barrels, or 7 per cent. The greater part of the increase was contributed by the United States and Mexico, although Russia, Argentina, and Japan also recorded small advances. Last year's output of the six principal petroleum-producing countries was:—United States, 281,104,100 barrels; Russia, 68,548,062 barrels; Mexico, 32,310,508 barrels; Dutch East India, 12,386,808 barrels; Roumania, 12,029,913 barrels; and India (including British Borneo), 7,400,000 barrels.

AMERICAN SHIPBUILDING.—At the commencement of August there were 389 merchant ships, representing an aggregate displacement of 1,260,978 tons, in course of construction in American shipyards. At the commencement of July the corresponding number under construction was 385, of an aggregate displacement of 1,225,784 tons. Orders for seven ships were placed in July, and three ships were completed. Of the 389 steel merchantmen which were being built at the commencement of August, 340, of an aggregate displacement of 1,004,523 tons, are to be launched during the present fiscal year (1915–16). The launching of a first vessel from the Chester Shipbuilding Company's yard, Chester, Pennsylvania (the old Roach yard) has just taken place. The vessel, which was named the Malmanger, is all steel, and is 401 ft. long by 54 ft. beam. She is to be propelled by Westinghouse geared turbine engines with three Scotch boilers, developing 3,000 h.p. The Pennsylvania Shipbuilding Company's yard at Gloucester, New Jersey, is approaching completion, and the first keel has just been laid. The company has contracts for six 7,000-ton tankers, and two 12,500-ton freighters, all for Norwegian firms.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Glasgow Pig-Iron Market.—There is nothing to report in connection with the pig-iron warrant market, the conditions of stagnation being still the most notable feature. The stocks in store remain at about 1,000 tons, as last week.

Scotch Steel Trade.—Like all other branches of industry closely connected with war work, the local steel trade continues in a state of activity probably entirely unknown in pre-war times; indeed, so overwhelming is the pressure for material of one kind or another, required both by our own and the Allied Governments, that manufacturers are finding the greatest difficulty in supplying the demands of these customers. Directly or indirectly all the steel at present being produced in the West of Scotland is immediately being swallowed up by the Ministry of Munitions or Admiralty contracts, and with this, not only is home mercantile business completely "off," but export also, except for war purposes. Despite numerous inquiries no steel is being rolled for export except that which goes to France, while in the home market consumers, considering the difficulty of delivery, are gradually ceasing to make inquiries for steel. "Discard" steel, and not much of that, is the only material of the kind that any of the manufacturers have for disposal. Steel for shell bars is still a heavy item of production. No change in price has taken place during the week.

Malleable Iron Trade.—There is no diminution of activity in the malleable iron trade, and alike in the iron and the steel departments the manufacturers are struggling with a pressure of work which keeps them constantly occupied and will continue to do so for many months. It is quite probable that in the near future it may be possible to procure better supplies of raw material, the freight market showing an easier tendency during the past week. "Crown" bars keep steady at the rate quoted a week ago—14*l.* 5*s.* per ton net f.o.b.

Scotch Pig-Iron Trade.—The abnormal demand for all grades of pig-iron continues, nor shows any sign of slackening off. Consumers' works in the West of Scotland absorb the makers' entire output, in consequence of which little or no stock can now be accumulated. This, of course, is all being required for war purposes, practically the only work at present being undertaken. Very little export business is being put through, licences being granted only with the utmost reluctance. At the moment rumour is busy with a report that the export of pig-iron will be entirely prohibited, but so long as the present licensing system gives the supreme control to Government it is not likely that any change will be made. Prices still keep firm.

Purchase of Leith Shipbuilding Yard.—Through negotiations conducted by Messrs. James Little and Co., the well-known Glasgow shipowners, shipbrokers and sale purchase brokers, the shipbuilding and engineering works owned by Messrs. Hawthorns and Co., Limited, Leith, have passed into the possession of Messrs. C. and H. Crichton, Limited, of Liverpool, and Messrs. James Little and Co., Limited, Glasgow, the latter firm having associated with them a private shipowning company of which they are the managing agents. The premises at Leith are well equipped, including a shipbuilding yard with seven building berths and first-class launching facilities and thoroughly up-to-date engineering sheds. In addition to shipbuilding operations on a rather extensive scale, the new proprietors expect to do very considerable business in ship-repairing. The new amalgamation has wide ramifications, the firms associated in the combine having varied and extensive interests.

Pather Iron and Steel Dividend.—As showing the extraordinary amount of business which has been overtaken in the local steel industry during the past year it is interesting to quote that the directors of the Pather Iron and Steel Company, Wishaw, have just declared an actual dividend of 10 per cent., making 17½ per cent. for the year. Twelve months ago, a loss of 2,321*l.* was shown by the accounts—now, after squaring everything, it has been possible to carry forward a credit balance of 175*l.*

THE KONGSBERG WORKS, NORWAY.—The Norwegian State, which owns these famous old silver mines and works, is contemplating several extensions; it is proposed to purchase the Gamlebro falls and to regulate the Laagen. The height of the falls is 14 m. and the capacity is calculated at 4,000 h.p.

WESTERN AUSTRALIA.—A supplementary Loan Act passed in December, 1915, authorises the raising by loan of 1,245,000*l.* for public works. The chief items of the proposed expenditure are:—Railways and tramways, 495,000*l.*; harbours and rivers, 107,000*l.*; water supply and sewerage, 130,000*l.*; and agricultural development, 102,000*l.*

THE FARADAY SOCIETY; GENERAL DISCUSSION ON "REFRACTORIES."—The Faraday Society will hold a general discussion on "Refractories" at their first autumn meeting, the date of which is provisionally fixed for Wednesday, November 8, 1916. The discussion will be presided over by Sir Robert Hadfield, F.R.S., president of the society, and the opening paper will be read by Dr. J. W. Mellor, of Stoke-on-Trent. Suggestions are invited from those specially interested in the subject as to any particular aspects which they would like ventilated or discussed, and those who are desirous of contributing to the discussion or who wish to show any exhibit at the meeting are invited to communicate with Mr. F. S. Spiers, Secretary of the Faraday Society, 82, Victoria-street, Westminster, S.W.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Cleveland pig-iron is rather quieter, but prices keep steady and firm. Sales to Scotland have practically ceased for the present, customers north of the Tweed having satisfied their needs to the end of October, which is as far ahead as they are permitted to purchase. Local foundries are in the position of having arranged for substantial deliveries up to the end of the year. Buyers of Cleveland iron are showing more disposition to trade direct with makers and thus save merchants' commission, notwithstanding that the former's terms are cash and the latter's credit. For home consumption No. 3 Cleveland pig, No. 4 foundry, and No. 4 forge are all quoted 87*s.* 6*d.*, and No. 5 is put at 91*s.* 6*d.* As regards foreign trade, business with neutral countries is still impossible. A fair amount is doing with France, and Italy, though still drawing most of her supply of pig from America, is buying in this market to some extent. Negotiations with Russia for shipment to that country via Norway are proceeding. Merchants here are interesting themselves in the sale of American iron to Scandinavia, and some cargoes have already been delivered to Denmark at high figures. Any Middlesbrough warrant iron that comes on the market for prompt shipment readily realises 100*s.*, though the recognised export market quotation of No. 3 Cleveland is 97*s.* 6*d.*, and makers are understood to be still selling to France at a little below that figure. No. 1 is 102*s.* 6*d.*; No. 4 foundry, 96*s.* 6*d.*; and No. 4 forge 95*s.* 6*d.* for shipment abroad.

Hematite Iron.—Conditions continue unfavourable to the transaction of new business in East Coast hematite iron. Stocks are practically nil and makers are sold well forward. Supplies on running contracts, however, are fairly well maintained, though some producers are in arrear with deliveries. Nos. 1, 2 and 3 remain at 122*s.* 6*d.* for home use and for shipment to France, and 140*s.* and upward for general export.

Stocks and Shipments of Pig-Iron.—Stocks of pig-iron are low and continue to be drawn upon to some extent. The quantities in makers' yards are mostly disposed of, and the stock of Cleveland pig in the public warrant stores here is approaching vanishing-point, standing now at only 13,630 tons, of which 13,594 tons are No. 3 quality, and 36 tons other kinds of iron deliverable as standard. Since the beginning of the month 2,055 tons of No. 3 and 350 tons of standard iron have been withdrawn from the warrant stores, a total reduction of 2,405 tons. Shipments of pig-iron from the port of Middlesbrough for the month of September promise to be returned at over 40,000 tons. For the previous month they reached 49,912 tons, and the clearances for September last year were officially given at 28,593 tons.

Output of Pig-Iron.—A good deal of idle plant is now quite prepared for re-starting, and an increase in the production of pig-iron by the blowing-in of additional furnaces at an early date is confidently expected.

Coke.—Coke continues in very good request for local use, and quotations are well maintained, though requirements are met by a much more than ample supply. Average blast-furnace kinds keep at 28*s.* at the ovens, and up to 30*s.* 6*d.* at the ovens is still asked for qualities low in phosphorus.

Foreign Ore.—The very large supplies of foreign ore that are steadily coming to hand enable consumers to add considerably to their already heavy stocks. Imports to Middlesbrough for September are well over 200,000 tons.

Manufactured Iron and Steel.—There are a large number of ordinary commercial inquiries in the market, but they attract little attention, so busily employed on Government work are manufacturers. Prices all round are very firm. The following are among the principal export quotations:—Common iron bars, 14*l.* 17*s.* 6*d.*; iron ship plates, 13*l.* 10*s.* to 14*l.* 10*s.*; iron ship angles, 13*l.* 15*s.*; steel ship plates, 14*l.* 5*s.*; steel ship angles, 11*l.* 2*s.* 6*d.*; steel sheets (singles), 18*l.* 15*s.*; steel sheets (doubles), 19*l.*; steel joists, 11*l.* 2*s.* 6*d.*; and heavy steel rails, 11*l.* 5*s.* Maximum prices to home buyers are: Common iron bars, 13*l.* 15*s.*; best bars, 14*l.* 2*s.* 6*d.*; best best bars, 14*l.* 10*s.*; steel ship plates, 11*l.* 10*s.*; steel ship angles, 11*l.* 2*s.* 6*d.*; steel joists, 11*l.* 2*s.* 6*d.*, and heavy steel rails, 10*l.* 17*s.* 6*d.* Among other quotations for home use are: Packing iron and steel (parallel), 11*l.*; packing iron and steel (tapered), 13*l.* 5*s.*; steel bars (no test), 14*l.* 10*s.*; steel hoops, 16*l.* to 16*l.* 10*s.*; and steel strip, 17*l.*

AMERICAN TIN-PLATES.—There was a heavy production of tin-plates in the United States last year. The output for 1910 was 1,450,821,000 tons; for 1911, 1,597,629,000 tons; for 1912, 1,965,659,000 tons; for 1913, 1,708,186,000 tons; for 1914, 1,939,785,000 tons; and for 1915, 2,201,825,054 tons.

GERMANY'S EXPORT OF IRON.—German iron works have informed their Danish customers that all export of iron from Germany would cease from the beginning of September. The stoppage was stated only to be temporary, but, on the other hand, no intimation was given as to how long it was likely to last. The cause was probably shortage of rolling stock, some being wanted for military and other purposes, and there is no reason to believe that there is to be a new departure in connection with the German export trade. The supply of German iron has been very irregular during the war, and there have been periods when it has almost come to a standstill.

NOTES FROM THE SOUTH-WEST.

Cardiff.—Less coal is being required by the authorities, and arrears in deliveries for vessels in dock have been made up to some extent. Buyers have been anticipating that coal will be more easily obtainable in the course of a few days, and they have accordingly been asking for concessions in prices. The authorities have been keeping a tight hold on export licences for neutral countries; middlemen holding supplies bought on contract at much lower prices have been willing to make reductions; and values have been unsettled for most classes of large and smalls. House coal has continued scarce and prices have shown hardly any change; patent fuel and coke have fully maintained late prices. The best Admiralty large steam coal has been, to some extent, nominal; secondary qualities have made 43*s.* to 45*s.*; Monmouthshire Black Veins, 44*s.* to 45*s.*; ordinary Western Valleys, 43*s.* to 44*s.*; Eastern Valleys, 40*s.* to 42*s.*; best bunker smalls, 30*s.* to 31*s.* and cargo smalls, 20*s.* to 25*s.* per ton. In bituminous coal, best households have made 25*s.* 6*d.* to 26*s.* at the pits; No. 3 Rhondda large, 42*s.* to 44*s.*; smalls, 32*s.* to 33*s.*; No. 2 Rhondda large, 34*s.* 6*d.* to 35*s.*; and No. 2 smalls, 25*s.* 6*d.* to 26*s.* per ton. The latest quotation for patent fuel has been 44*s.* to 46*s.* per ton. Special foundry coke for export has brought 62*s.* 6*d.* to 65*s.*; good foundry coke, 60*s.* to 62*s.* 6*d.*; and furnace coke, 50*s.* to 55*s.* per ton.

Western Trade Matters.—The first interim dividend of the Town Line, Limited, for 1916–17, is 5 per cent., free of income-tax, payable in October. A final dividend of 10*s.* per ordinary share is to be paid for 1915–16; this makes a total distribution of 25 per cent. for the year, 2,747*l.* being carried forward; no less than 47,000*l.* has been set aside to meet the excess profits duty and income-tax. Including the amount brought forward from 1914–15, there was a balance of 83,337*l.* available for dividend; the final balance carried to the credit of 1916–7 was 2,747*l.*—The Western Counties Shipping Company divided at the rate of 20 per cent. for 1915–16, carrying forward 3,550*l.*—Lord Milner expresses his opinion that before a price limitation scheme can be proposed for coal, employers must be safeguarded against any further demands for increased miners' wages, and he states that he has had little encouragement from the men's leaders at present to induce him to suppose that any guarantee can be given upon the subject. This appears to be a vital admission.—The directors of the Cardiff Channel Dry Docks and Pontoon Company, Limited, recommend an interim dividend for the six months ending September 30 at the rate of 6 per cent. per annum.—The South Wales branch of the British Empire Union, which has for its object the imperial consolidation of the Empire and the development of trade and commerce within the Empire and with our Allies, has received considerable support from leading public men, and now that winter is approaching it has been decided that mass meetings shall be held in the important centres of South Wales; considerable propaganda work has already been done.—The directors of the Port Talbot Graving Dock and Shipbuilding Company, Limited, recommend a dividend of 10 per cent., free of income-tax, for 1915–16; a similar distribution was made for 1914–15.—The dividend of the Tempus Shipping Company, Limited—which is under the management of Messrs. Seagler and Co., Cardiff—recommend a dividend of 20 per cent. (1*l.* per share) for 1915–16, free of income-tax.—Lord Rhondda is promoting an inquiry into the probable position of the coal trade after the war; the inquiry is proceeding upon exhaustive lines and important results are anticipated.—Several disputes in the South Wales coal field have been settled by a joint committee appointed by the Conciliation Board. Consideration of a continued stoppage at the Gelli colliery, owing to the workmen concerned having declined to accept the terms of a settlement made in August, 1914, has been adjourned until October 5.—Steamers arriving too late to begin loading coal for France in September are to rank first against licences extending from October to December.—At a meeting of anthracite miners at Swansea on Saturday, Mr. J. D. Morgan (agent) stated that arrangements had been made for the release from the army of about 17,000 miners now in military camps in order that the men might return to work in the mines, which are now suffering from shortage of labour, while a larger output is required both on home account and for our Allies.—At a meeting at Swansea on Saturday it was decided to call a conference with a view to agitating for a repeal of income-tax upon wages.—On Monday the wages of Forest of Dean colliers were advanced a further 10 per cent., pursuant to a decision arrived at by associated coal owners and the men's trade union wage committee.—On Saturday the Cardiff guardians decided to refuse to pay the additional 2*s.* 6*d.* per ton authorised by the Board of Trade to be charged on coal supplied since June.

SHIPBUILDING IN GERMANY.—The Flensburg Shipbuilding Company has, for the year 1915–16, earned net profits of 653,662 marks, against 794,452 marks for the previous year. The dividend was again fixed at 10 per cent. The report states that the company has more orders in hand than a year ago and will be fully employed for a long time to come.

PRICE OF COAL (LIMITATION) ACT, 1915.—As has been stated on more than one occasion in the House of Commons, an application has been made to the Board of Trade by the Forest of Dean Joint Minimum Wage Board for an increase in the standard amount under the Price of Coal (Limitation) Act as respects the mines in their district. This application is now receiving the consideration of the Department.

THE ACCIDENT TO THE QUEBEC BRIDGE.

(*For Description, see Page* 304.)

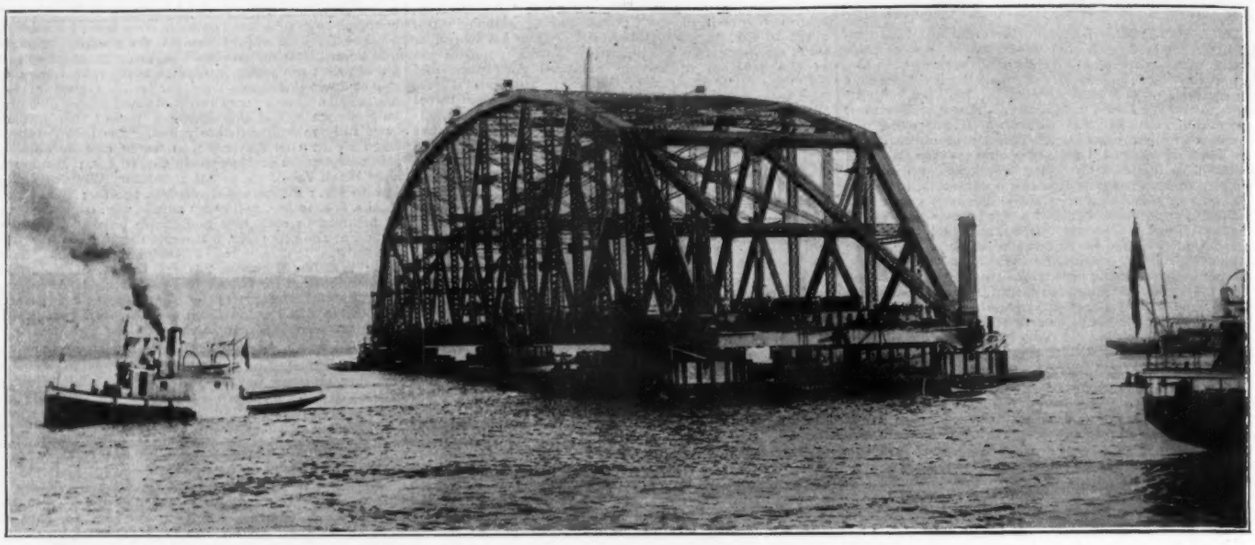


Fig. 1. Centre Span Afloat, Ready for being Towed into Position.

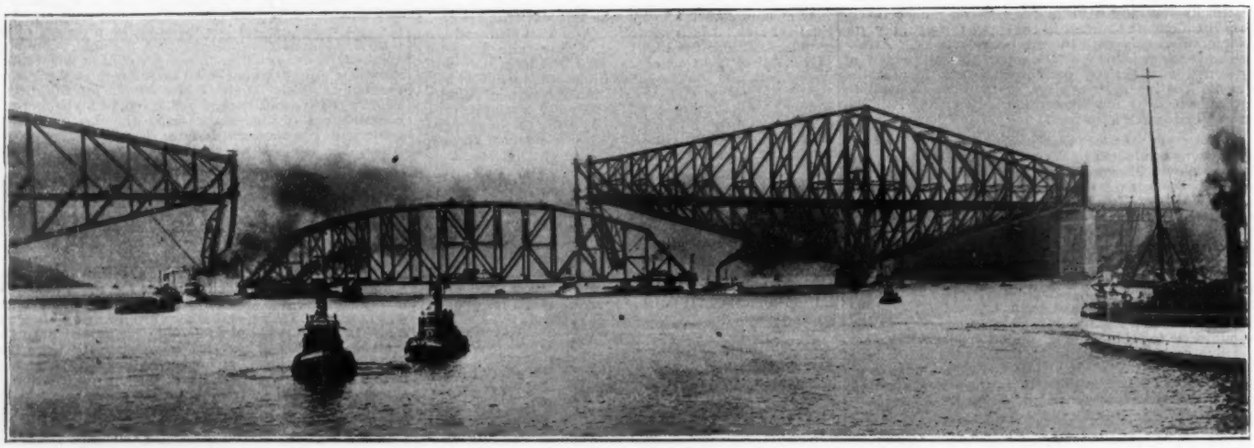


Fig. 2. Centre Span Nearly in Position for Lifting.

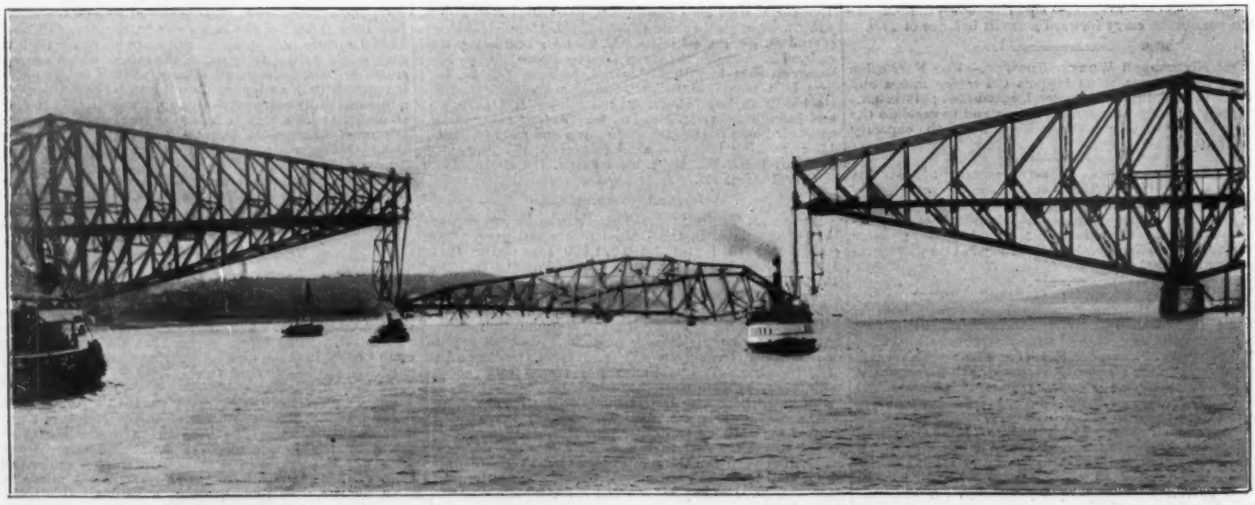


Fig. 3. Collapse of Centre Span.

DETAILS OF LOCOMOTIVES, CLASSES "K4S" AND "L1S;" PENNSYLVANIA RAILROAD.

MR. J. T. WALLIS, GENERAL SUPERINTENDENT OF MOTIVE POWER.

(*For Description, see Page 295.*)

Fig. 168.

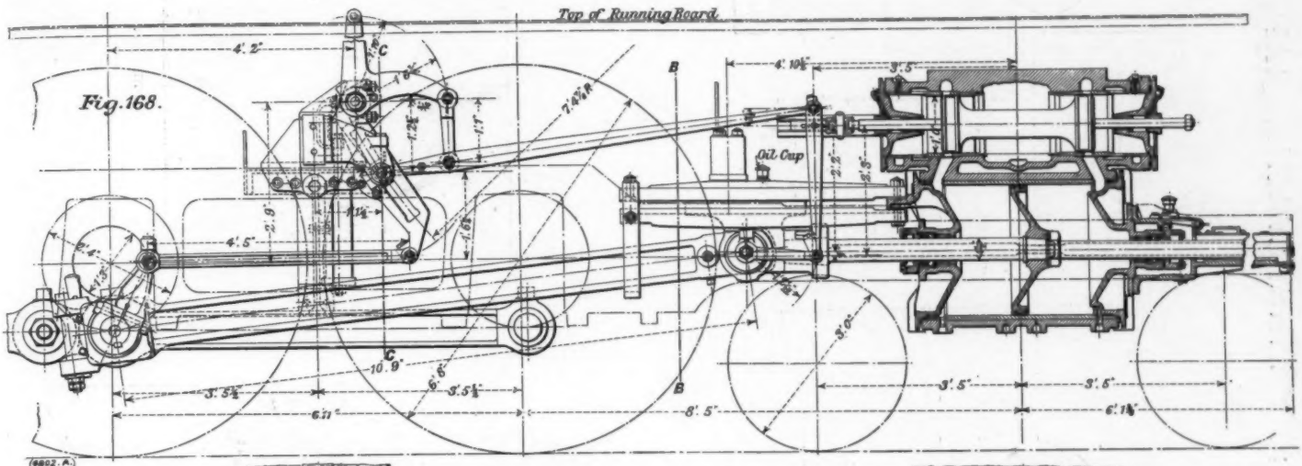


Fig. 169.

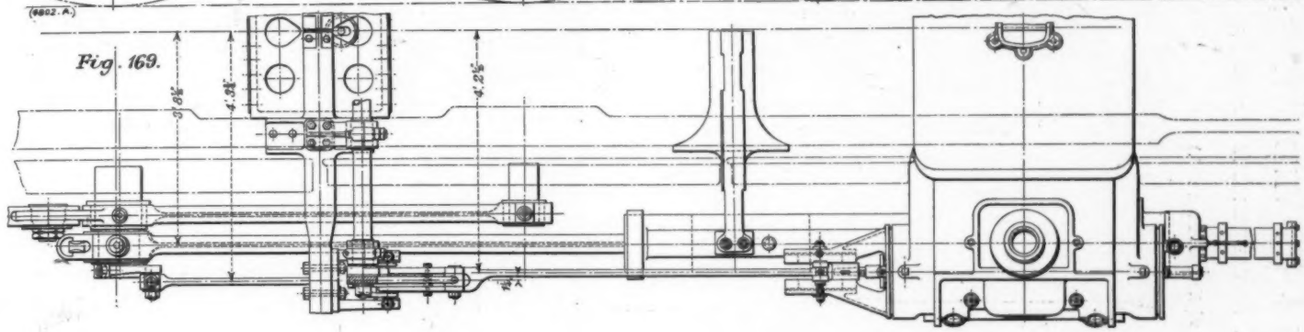


Fig. 170. SEC. C.C. LOOKING BACKWARD.

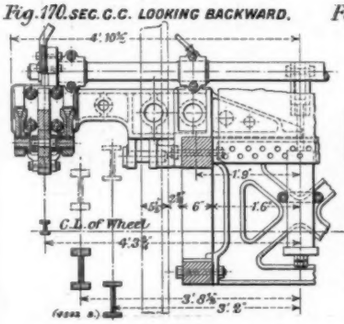


Fig. 171. SEC. B.B. LOOKING FORWARD.

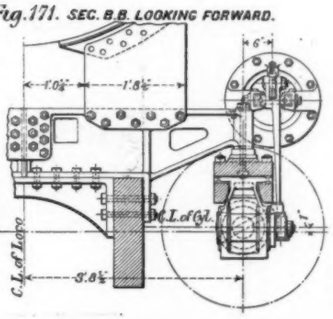


Fig. 172.

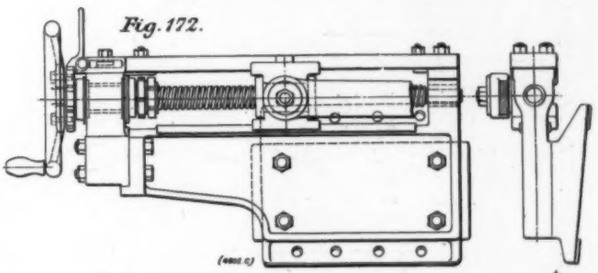


Fig. 173.

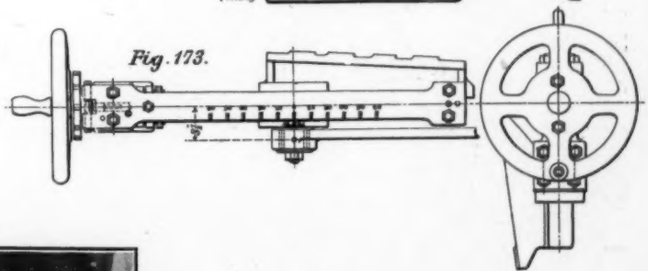


Fig. 174

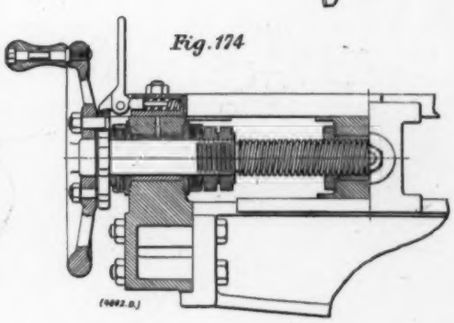


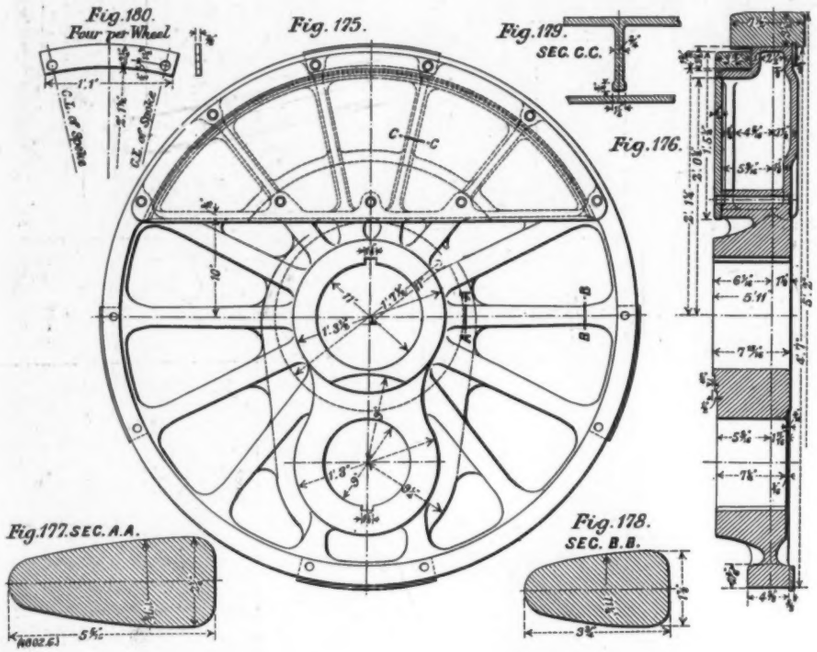
FIG. 191. FIG. 192.

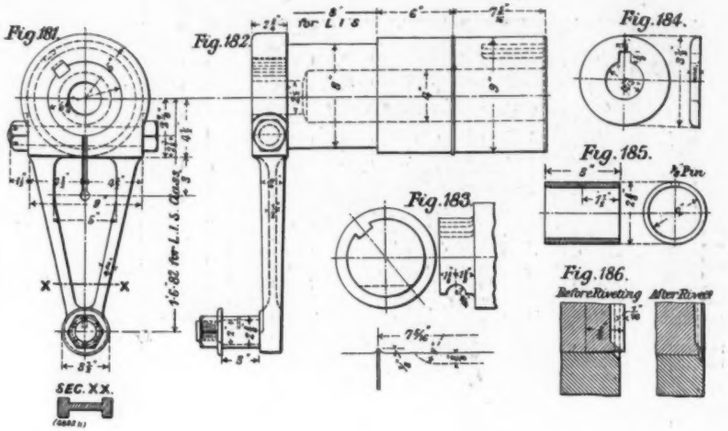
(*To face page 294.*)

DETAILS OF LOCOMOTIVES, CLASSES "K4S" AND "L1S;" PENNSYLVANIA RAILROAD.

MR. J. T. WALLIS, GENERAL SUPERINTENDENT OF MOTIVE POWER.

(*For Description, see Page 295.*)





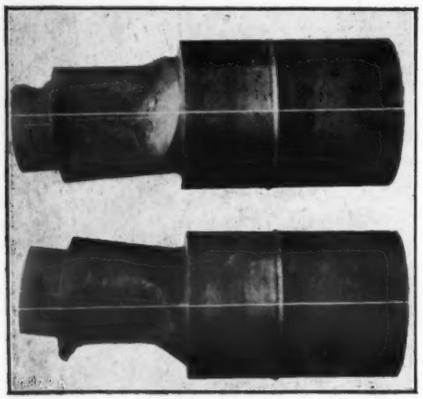


Fig. 187.

Fig. 188.

Fig. 189.

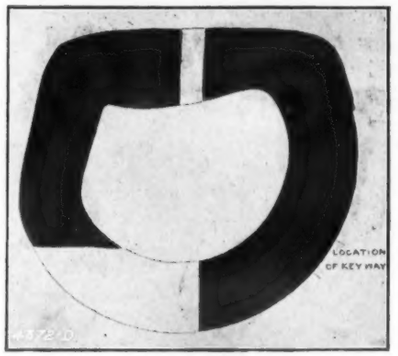
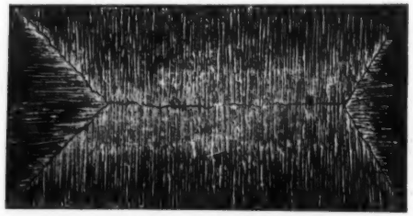


Fig. 190.

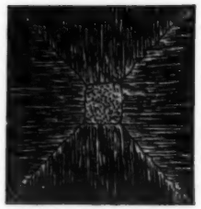
SOME PROPERTIES OF INGOTS.

(*For Description, see Page* 315.)

FIG. 1.—Cross-section of chrome-steel ingot.



a



b

c

FIG. 2.—Diagram of crystal-growth in ingots.

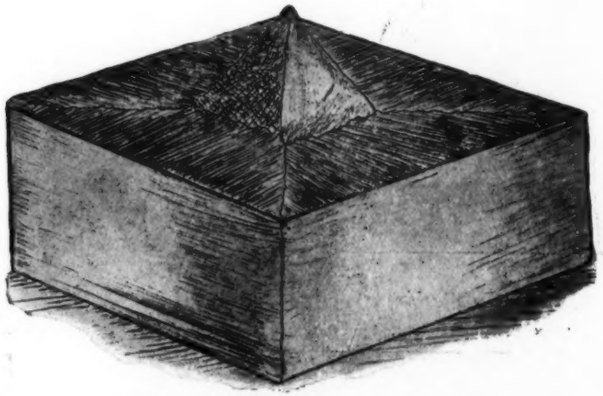


FIG. 3.—Partly exposed base pyramid in wax ingot.

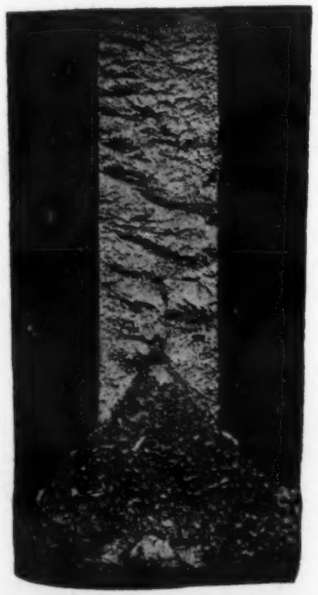


FIG. 4.—Exposed pyramid in base of steel ingot.

FIG. 5.—Equiaxial crystals of steel formed by slow freezing.

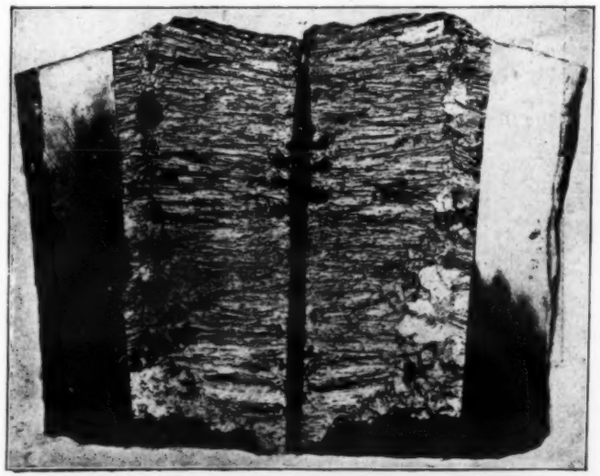


FIG. 6.—Needle-shaped and equiaxial crystals in same specimen.

(*To face page* 314.)

SOME PROPERTIES OF INGOTS.

(*For Description, see Page* 315.)

FIG. 10.—Partly fluid crucible ingot intentionally inverted.

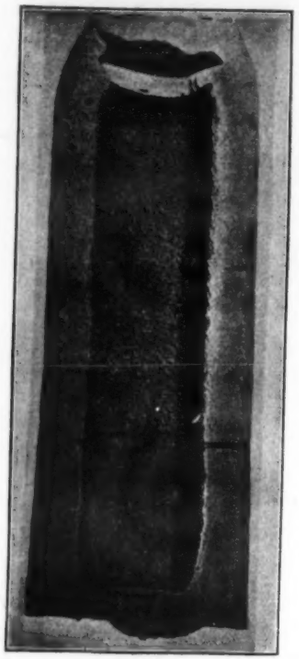


FIG. 11.—Open hearth ingot intentionally bled.

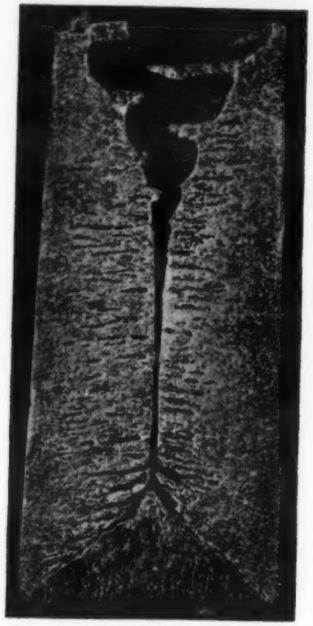


FIG. 12.—Diagonal contraction cavities.

FIG. 13.—Rupture along diagonal plane of steel ingot. × 25.

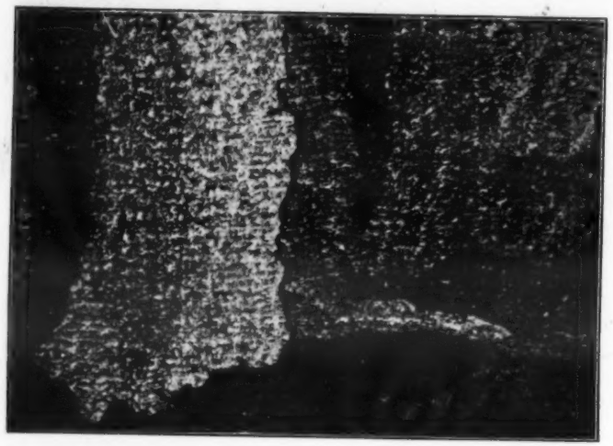


FIG. 14.—Portion of Fig. 1 enlarged to show crack between crystals.

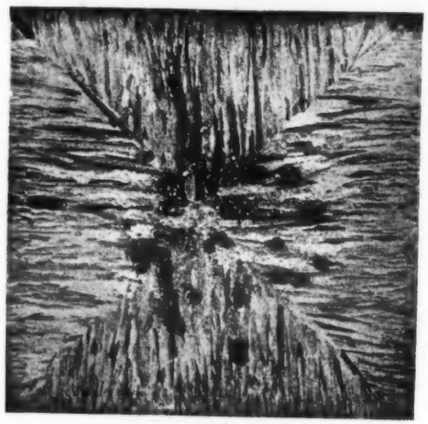


FIG. 15.—Cracked surfaces corroded by pickling.

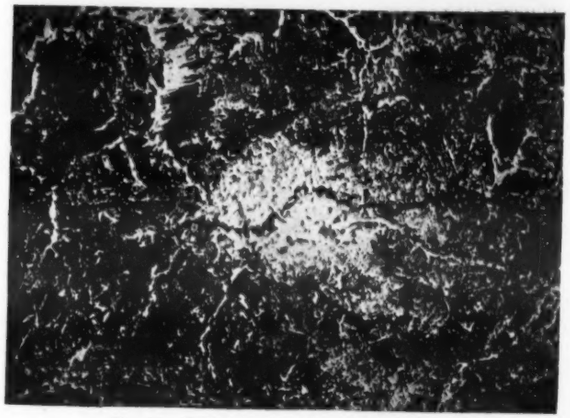


FIG. 16.—Radial crack in 30-ton steel billet.

(*To face page* 315.)

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With Two One-Page Plates of DETAILS OF LOCOMOTIVES, CLASSES "K 4 S" AND "L 1 S," PENNSYLVANIA RAILROAD; and Two One-Page Plates of SOME PROPERTIES OF INGOTS.

NOTICE OF MEETING.

THE MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.—Thursday, October 5, at 3.30 p.m., at the Great Northern Hotel, Leeds. The following paper will be read:—"Widening of the Upcast Shaft at Tinsley Park Colliery," by H. J. Atkinson (Student). The following papers will be open for discussion:—(i) "Fuel Economy at Collieries," by F. F. Mairet. (ii) "Health of Old Miners," by Dr. Haldane.

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In view of the restrictions now imposed by the Government on the importation of paper, and of the consequent shortage of supplies, readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk. Owing to the scarcity of paper it will be impossible in future fully to provide for a chance demand for this Journal.

ENGINEERING.

FRIDAY, SEPTEMBER 29, 1916.

FINANCIAL FACILITIES FOR TRADE.

THERE has just been issued the report of the Government Committee appointed "to consider the best means of meeting the needs of British firms after the war as regards financial facilities for trade, particularly with reference to the financing of large overseas contracts, and to prepare a detailed scheme for that purpose." The Committee have been prompt in carrying out their work and their decision in favour of a trade credit bank, if effectively carried out, will profoundly influence the future course of British trade. The Committee consisted mostly of important members of the directorates of English joint stock banks, and it is of great significance that the result of their considered judgment is to advocate the establishment of such a bank, thus fully and finally endorsing the numerous complaints of traders that the present system of English joint stock banking did not by any means afford the fullest financial facilities that the trade of the Empire demanded. We have time and again tried to demonstrate this deficiency in our commercial organisations and have shown that in consequence of this lack of support the foreign banks, which established branches in this country and in various parts of the world where British manufactures sought markets, were able to obtain a large influence over British trade. The outbreak of the present European war brought home to us the full realisation of the extent and power thus obtained. The immediate effect was to bring trade both at home and abroad to a standstill, and it became necessary for the British Government to give generous guarantees and devise many new and problematical measures for the support of our foreign trade during the war.

Apart, however, from the great advantage now given to the project of a trade bank through being advocated by a body composed mainly of those who in the past have been, if not openly antagonistic, at least passive in their support, the report does not contain much more than the arguments which have always been used in endeavouring to obtain more liberal financial assistance for trade. Indeed, in some respects, for instance by omitting in its proposed programme all mention of assistance to shippers, it does not embrace some of the most prominent features which have been common practice in everyday transactions of the foreign bank. Moreover, the scheme of the proposed bank, instead of being prepared in detailed form as required by the terms of reference to the Committee by the President of the Board of Trade, is left, probably purposely, very vague. The greater part of the report is devoted to quoting examples whereby, in the opinion of the Committee, the proposed bank might operate advantageously, and here again most of these are common knowledge and are daily carried out in the ordinary course of business by foreign banks. On the other hand, much is made of the care which must be exercised to avoid in any way injury to the business of the present banks. The very evident solicitude for conserving existing banking interests is in great measure due to the constitution of the Committee, and the same explanation is also applicable to the openly-expressed object of enabling the present banks to have great influence on the procedure of the new institution, which, judging from their past practices, may not materially assist its future development, but rather the reverse. Thus the Committee, although they have boldly crossed the Rubicon, lay down restrictions which they consider would keep the scheme within bounds. In this they display a lack of courage on the one hand, and a groundless fear, on the other, that the new institution would affect existing banks. On the contrary anything which develops foreign trade must be advantageous to the whole banking interest. It is, for instance, suggested that the proposed new bank should not receive deposits at short notice, and should only open current accounts for customers who undertake to avail themselves of its overseas facilities. The effect must disastrously limit the resources of the new bank, for it is obvious that if the new bank is not to be allowed to accept deposits at short notice and current accounts, it will be dependent almost exclusively on the extent of its capital. The Committee suggests the amount of capital necessary for the purpose for which the new project is to be created as 10,000,000*l.*, notwithstanding that this trade bank is to support the whole volume and wide ramifications of British trade. Not content with this narrow view, there is the further remarkable proposal that only one-quarter or one-half of this sum should be offered for subscription to begin with, and that further issue should be made afterwards, "if possible," at a premium.

Was there, we wonder, before the Committee a statement of the figures of the capital and reserves, together with those of the current and deposit account balances of the most important foreign and colonial banks undertaking similar work to that which is to be entrusted to this new British Trade Credit Bank, in order to allow them properly to apportion the necessary financial foundation for the scheme? On what grounds they made their decision it is impossible to say, for if we take the figures of only six of the most important Continental banks trading in London immediately before the war, we realise how insufficient is a capital, to begin with, of 2,500,000*l.*, with limitations in deposits. The figures of these six banks, given on the next page, show an average in capital and reserves of 17,300,000*l.* and in deposits and current account of nearly 50,000,000*l.*—together 67,300,000*l.* sterling. How far can 2,250,000*l.* combat the influences of such foreign undertakings, especially when it is remembered that the total of British imports and exports for 1913 amounted to 1,400,000,000*l.*? Presumably the financing of some part of the transactions appertaining to this trade, as well as for its expansion, is to be the object of the new institution. As the foreign banks have the advantage of current and deposit account balances to such a great extent to assist them in their trade transactions, the denial of such liquid capital to the British Trade Bank must enormously handicap the latter.

It is also unfortunate that on one of the most important points in connection with the establishment of the new bank the report is studiously silent, although the Committee were asked to prepare a detailed scheme. Nothing whatever is suggested as to whether, in addition to a central institution, presumably situated in London, a branch is to be established in every important industrial centre. Until this point is settled it is obvious that the whole scheme is in the air. Undoubtedly it is necessary, if the new bank is to have the weight and character which is proposed, that there should be many branches; in such case the difficulties attending the successful inauguration of the new project with the meagre capital suggested are immeasurably increased. While British traders are anxious for the advantages which a special trading bank would confer, they would doubtless prefer, instead of the crippled institution, some reform and development of the facilities afforded by the network of branches of joint stock banks with which the country is already covered. Could existing banks, by a rearrangement of capital and an alteration in their system of accepting deposits, not establish a trade bank department in connection with their most important branches? Most of the greater banks have already established a foreign banking department, and although the arguments ordinarily

(To face page 315.)

used against the formation of trade banks apply with equal force and weight against foreign banks, yet the foreign bank departments of English banks have undoubtedly had a beneficial effect on purely English business. Indeed it was because the foreign banks attracted English bank business that the latter were compelled in self-defence to enter their arena. In this respect it is to be noted that the new trade bank is also to be allowed to open foreign and credit departments, presumably because the existing banks have found these departments so lucrative.

But there are immense advantages to be derived from a new trading bank with sufficient financial support and wide and broadly-interpreted ramifications. The Committee strongly desire that the new bank should have all the support it can possibly get, and suggest that "the new institution, without coming under Government control, should receive as much official recognition as possible." They emphasise their opinion that British officials abroad should place at the disposal of the new bank all the information in their power. This raises the whole question of our Consular service, which in the past has been most inefficient from the traders' point of view, largely because the British representatives abroad are often foreign-born or trade rivals. It is a great pity that the report did not urge the reformation of this service, especially as until this is done no trade bank can possibly prosper to its full extent. The Committee may have felt that this was beyond their powers, but they should have more fully detailed the sources whence the trade bank is to get its assistance in foreign countries.

Another defect in the report is the evident intention of the Committee to insist that the existence of the new bank is solely to make profits. All the examples given by them where the assistance

Table Showing Financial Resources of Six of the Foreign Trading Banks with Branches in London.

	—		Deposits and Current Account.
Disconto Gesellschaft	capital ...	10,000,000	33,000,000
	reserves...	4,000,000	
Dresdner Bank ...	capital ...	10,000,000	48,000,000
	reserves...	3,000,000	
Deutsche Bank ...	capital ...	12,500,000	102,000,000
	reserves...	9,000,000	
Crédit Lyonnais ...	capital ...	10,000,000	70,000,000
	reserves...	7,000,000	
Société Générale ...	capital ...	10,000,000	23,000,000
	reserves...	5,000,000	
Compt. Nat.	capital ...	8,000,000	20,000,000
	reserves...	15,000,000	
Total		103,500,000	296,000,000

of the new bank is required, and the various suggestions as to the help it may be disposed to supply, are to be looked at solely from the point of view of profit to the bank. It is very apparent that if a trade bank is established on proper lines there is no doubt that it will be offered a plethora of profitable business, and be able to choose ultimately its risks. Its success will therefore be undoubted. If losses were made during the first few years of its inception, they would undoubtedly be recouped as its operations and strength grew. In view of such a contingency, the Government, as a matter of policy and Imperial interest, might guarantee a modest return on the capital for the first few years, on similar lines to those on which it recently undertook such a liability to assist British and Italian commerce. Indeed, it would almost seem that the bank should be a Government department, were it not for the unfortunate fact that if it were so it would speedily become enmeshed with red tape, and much of its usefulness would be lost.

The proposal to institute an information bureau is certainly to be commended, as the absence of such a department has in the past been a source of great danger and loss to the trading community. This raises the subject of the staff. The Committee make valuable suggestions on this point. They would almost seem to have approached the question from the point of view of the ordinary employer, and to demand that applicants should possess proper qualifications. This is undoubtedly right, for in an institution of this class it will be necessary always to have a staff specially trained in its various fields in order to carry on its work successfully. It would seem that the question of "personality" is recognised here to be of importance, a welcome change to the belief, largely held at present in banking circles, that great institutions with many branches have sufficient momentum to run by themselves, with the consequence that all branch business particularly is run by a system of rules which require much persistence in overcoming them in the interests of the trader. Every endeavour is to be made, it would seem, to ensure that the members of the staff of the new bank should continually be in touch with the *clientèle* of the bank, and take every opportunity of associating with its customers, ascertaining the conditions of business and customs of foreign centres, in order to be able to advise traders and customers to the best advantage. Another proposed innovation is the reference to technical committees of projects where the special information of the members of such committees would be valuable. This is an important step in advance, and should materially benefit commerce.

Altogether, the report distinctly marks an epoch, as it brings the proposal for a trade credit bank within the range of "practical politics." But for this very reason it is the more to be regretted that the proposed trade bank should be so seriously handicapped by the limitation of the capital to a comparatively infinitesimal sum, the recommendation of limiting deposits and current accounts, due to obvious anxiety to avoid any appearance of encroachment on ordinary banking business, and to the nervousness as to trading profits. It cannot be too emphatically stated that the establishment of such a bank is of vital importance in the coming trade war, when every means must be employed to benefit the trade of the Empire, and that there is not the slightest doubt that if the whole project be boldly carried out on broad lines with adequate capital it will be a great and instantaneous success, and very materially contribute to the recapture by Britain of that part of the trade of the world which is our due and which has in the past been slipping from our hands.

WATER IN COAL.

Coal always contains some water, even if apparently dry. A distinction is frequently drawn between the "free water," or accidental moisture, and the "water in combination" held by the coal in some badly understood way. The demarcation line is anything but sharp, and it is impossible to remove all the free water without affecting the combined water; yet there are differences in the vapour pressures. But the term "water in combination," suggesting chemical combination, of which there is no evidence, is not well chosen. Conducting an investigation of the "Properties of the Water in Coal," on behalf of the United States Bureau of Mines, Messrs. Horace C. Porter and O. C. Ralston (Technical Paper 113) propose the term "inherent" water. Air-dried Appalachian coal, they find, contains about 2 per cent. of water, sub-bituminous coal up to 18 per cent. of water. The fairly dry coal is hygroscopic, and may re-absorb up to 7 per cent. of water when transferred from an atmosphere of 40 per cent. of relative humidity to an atmosphere of 75 per cent. Mine air, generally of about 40 per cent. of humidity, dries the coal; properly dried, powdered coal is decidedly hygroscopic. Superficially, coal further retains water during the washing process or when wetted, and that percentage depends largely upon the size of the particles; coal passing through a ¼-in. mesh will retain from two to seven times as much water as nuts of 1-in. diameter; but those differences disappear with air-drying.

The free water is determined by air-drying; the inherent water (which has a vapour pressure less than the normal) is generally determined by drying 1 gramme of air-dried powdered coal for one hour in a current of dry air at 105 deg. C. The method is open to objections; for on the one hand even prolonged air-drying may leave in the coal several per cent. of moisture (it left 2.7 per cent., *e.g.*, in the case of Wyoming sub-bituminous coal after 10 days of drying at 20 deg. C.), and, on the other hand, the high temperature of 105 deg. is not borne without some oxidation and decomposition of the coal. Hence desiccators (sulphuric acid or phosphorus pentoxide; calcium chloride is unsuitable) are often used in *vacuo*, and these same agents (especially sulphuric acid of various concentrations) were also resorted to by Porter and Ralston in determining the vapour-pressure curves of the water in coal. Samples of 100 grammes of pulverised coal were kept in open bottles over sulphuric acid, the air being exhausted until the pressure was less than 5 mm. of mercury above the aqueous tension; thus the vapour tensions of the water in the coal and of the acid (of suitable dilution) would balance one another. With this procedure the coal would sometimes be hydrated and sometimes be dehydrated, being itself more or less dry than the acid, and the vapour pressure would not be the same, for the same moisture percentage, at periods when the coal was being dried as at periods when it was being made more moist. The difference would partly be explained by the very slow rate of exchange of pressure near equilibrium, and the case is analogous to that of heating and cooling curves. There were also striking differences between different coals of the same water content of 3 per cent., *e.g.*, a Virginia coal of this water percentage gave a normal water pressure, a Pittsburg coal 83 per cent. of the normal, Illinois coal 18, and Wyoming coal as little as 4 per cent. of the normal pressure; these coals would thus have very different rates of drying.

Another effect studied was the heating produced when coal, dried, sometimes at 110 deg. C., or partly dried, was wetted with water. This thermal effect varied directly as some function of the relative vapour-tension deficiency just mentioned, and the two phenomena are interrelated. The effect was observed in a special calorimeter consisting of a nickel cup of 70 cub. cm. capacity paced in a Dewar-vacuum bulb. The Wyoming coal produced on wetting 19.2 cals. per gramme of dry coal, lignite from Dakota 25.5 cals., Illinois bituminous coal 6.8 cals., Pittsburg coal (also bituminous) 1 cal. Accepting the specific heats of these coals which the same experimenters had previously determined, these amounts of heat liberated would, they point out, raise the temperature of these coals by 43, 64, 20, 4 deg. C. respectively, assuming that no heat was lost. A sample of infusorial earth, similarly treated, gave 2 cals. per gramme, and Rodewald and Kattein had found 28.8 cals. in wetting wheat starch. The fineness of the coal did not appear to make any difference in these high figures. On the other hand, it seems likely that, in wetting a coal, water would not be able to enter the completely dehydrated inner pores as readily as partly dehydrated larger pores, and remoistened coal might hold water so firmly that this water would practically not show any vapour pressure. It is interesting to note that toluene behaved, in such wetting experiments, very much like water; it also heated the coal, the Pittsburg coal even more than water, the Wyoming coal much less. Wetting with toluene also heats finely divided silica, we should add.

These latter experiments with toluene throw some doubt on previous determinations, by H. C. Porter and G. B. Taylor, of the relative specific heat of dried and of undried coal. In those experiments it had been assumed that the mixing of dry coal with toluene (water was avoided) would have a very small and slow thermal effect. Messrs. Porter and Ralston now correct their former values, but confirm their statement that the molecular heat of the inherent water is smaller than that of free liquid water; that conclusion seems to require further confirmation, however.

In explanation of the various phenomena they suggest that a certain part of the coal substance is in the colloidal condition; that part, probably deposited at some stage as a colloidal gel from suspension in water, would be larger in the cretaceous coals and lignites than in the more highly metamorphosed bituminous coals. The colloidal particles would retain the water in the peculiar state of the "inherent" water, and the heat produced might be due to the penetration of the liquid into minute capillaries and to the formation of a colloidal condition. We do not quite understand this last suggestion; but it is generally understood that the complex adsorption effects are strong in colloids.

THE INSTITUTE OF METALS.

(*Concluded from page* 288.)

DEVELOPMENT OF THE SPELTER INDUSTRY.

ON members re-assembling at 8 p.m., Wednesday, September 20, the President called on Mr. Ernest A. Smith to read his paper entitled "The Development of the Spelter Industry," remarking that the question of zinc production was one of national importance, and it would be gratifying if the Institute of Metals could make some really serviceable contribution to the subject. This was a very long paper, which would occupy some 25 columns of ENGINEERING, and covering the spelter industry from many points of view. It is quite impossible to deal with it in the form of an abstract. All that we can do is to give a list of the various headings, so that the general scope of the paper may be understood. These are (1) Historical Note, (2) Progress of the European Zinc Industry, (3) Progress of the American Zinc Industry, (4) Asiatic Zinc Industry, (5) Present-Day Zinc-Smelting Centres and Output of Spelter, (6) Zinc Market, (7) The Spelter Convention, (8) Ores of Zinc, (9) European Sources of Zinc Ores, (10) American Sources of Zinc Ores, (11) Australian and Other Sources of Zinc Ores, (12) European Zinc Ore Trade, (13) The Metallurgy of Zinc, (14) Treatment of Zinc-Bearing Complex Ores, (15) Smelting Zinc-Bearing Complex Ores, (16) Electric Smelting of Zinc Ores, (17) Hydro-Metallurgical Processes of Zinc Extraction, (18) Industrial Applications of Zinc, and (19) Future of the Zinc Industry. It will be seen that the discussion turned very largely upon the flotation processes in use in Australia and upon the preparation of crucibles and retorts. These two subjects formed only a very small proportion of the paper itself, and were not dealt with in it at any very great length.

Mr. H. K. Pickard opened the discussion. He remarked that, in respect particularly to the flotation treatment of ores, the paper was hardly up to date due, no doubt, to the circumstance that it was written nearly twelve months ago. For instance, Professor Bacon had been quoted by the author as saying, in 1915, that "the great problems at present in the metallurgy of zinc are in concentration of the ore and in the treatment of flotation concentrates." The speaker disagreed; concentration of the ore was one of the least of the problems in connection with the metallurgy of zinc; flotation had settled the difficulty for good. Professor Bacon might, however, have referred to oxidised ores, but the speaker scarcely thought so, judging by the words "treatment of flotation concentrates." In pre-war times Broken Hill had, by means of flotation concentrates, been able to satisfy one quarter of the zinc requirements of the world, an effective answer to Professor Bacon's suggestion. The speaker regarded as at least ambiguous the author's observation that, "in addition to concentrate suitable for smelting, the flotation processes produce a certain amount of slime, the metallurgical treatment of which is the great problem of smelters at the present time." The flotation process did not produce slime, although capable of concentrating slime; indeed, this was perhaps its chief virtue. In most concentration processes it was necessary to remove the slimes from the crushed ore and deal with the sand section separately. The flotation process would concentrate sands and slimes together with higher net recovery of metal in the form of concentrate than in the case of other known system. He would go so far as to say that he believed any zinc blende ore at all amenable to concentration would yield 95 per cent. of its value in high-grade concentrate suitable for smelting. The fact that Continental zinc smelters had been able to deal with the large quantities produced from Australia, always containing a certain amount of slime, did not suggest that slimy material presented problems. The author remarked that metallurgists were "making every effort to find a solution to the commercial treatment"—of flotation concentrates presumably—but the speaker would say that the Germans had done this with all zinc concentrates. He did not regard as correct the author's statement that German smelters preferred zinc ores containing sufficient lead and silver to yield a residue which could be sold to lead smelters. The zinc blende in the concentrates carried a certain amount of silver, to recover which a certain amount of lead must be present. The flotation processes producing these concentrates might produce a concentrate almost free from lead. The German smelters, however, called for a concentrate containing 8 per cent. of lead, the lead, obviously, to act as collector for the silver. Silver being present, they required the lead. If it were a question of plain zinc smelting, the speaker did not suppose zinc smelters would desire a concentrate with lead. The speaker could confirm the author's reference to Mr. Moulden's statement that he had successfully treated by distillation zinc ores containing 20 per cent. of lead.

The speaker had been connected with the briquetting process for zinc lead ores, treating several thousand tons of lead slimes (without sands), the average yield being 25 per cent. zinc and 25 per cent. lead; no trouble arose from the presence of lead. Further confirmation was contained in an article by Mr. Theo. Hoover (*Mining Journal*, August 13, 1910), in which mention was made of the treatment of some 600 tons of ores containing 24.38 per cent. of lead. The writer of the article stated that by briquetting he obtained 33 per cent. more ore in the retort than by loose charging, the destruction of retorts being less than with ordinary zinc smelting. The briquetting operations to which the speaker had referred were not a commercial success, the price of metals at about that time (1901) being so extremely low as to leave little profit. A plant adapted for carrying out the process was, however, erected in Australia. It was the first zinc plant put up in that country, and difficulties incidental to the starting of a new industry prevented any marked success, while the development of the flotation process, giving zinc concentrates more or less free from lead, removed the occasion for treating mixed products. The author had referred to the limits of iron approved by zinc smelters, but with briquetting the quantity of iron was of no consequence. Ores containing 20 per cent. of iron had been satisfactorily treated by Americans, as had also those containing lime and fluorspar, and all kinds of modified briquetting processes were used in America.

With regard to new plants to deal with the British Empire supply, the speaker considered that the author had laid down the essential conditions when dealing with present-day zinc-smelting centres. Zinc works could not be dumped upon just any site if success were to be achieved. The industry had developed in Australia in spite of climatic conditions. He believed the Proprietary Company had found sources of suitable clay, although he remembered when half the clay had to be imported from England. Clay for retorts needed special qualities, and although two clays might be practically alike on analysis, it would not follow that each was equally good for the manufacture of zinc. He considered, from personal experience, the climatic conditions of Australia adverse to the industry if carried on by the ordinary retort process. With regard to the wet processes, electrolysis of zinc sulphates was not altogether easy; the purity and strength of the solutions had to be considered, but to get purity was not beyond the skill of the chemist, and, generally, the earlier difficulties were being overcome. He disagreed with the suggestion that work at Anaconda was still in the experimental stage; as a fact some 2,000 tons of ore were being treated daily by the flotation process, and he imagined that the amount of concentrates treated by electrolysis was considerable. As to the future of the zinc industry, he could only hope that, with the assistance of the Government and private enterprise, this empire would hold its own.

Dr. Robert Mond stated that he was not a zinc smelter, although he had done some zinc mining in North Wales and had followed the flotation and other separating processes in endeavouring to get as much zinc and lead as possible out of the ores. He had also been engaged in working out hydro-metallurgical processes. Difficulties of an unexpected nature, for which it was hard to find reasons, had to be discovered before they could be overcome. With regard to the zinc dust nuisance so common with concentrates of the iron ores in Germany and elsewhere, efforts were made to remove this trouble by chlorination, or by oxydising the zinc sulphide into zinc sulphate, recovering the zinc by lixiviation of the sulphate. A number of investigators had unsuccessfully endeavoured to get the zinc chloride in a solid state by double decomposition of the chloride with sodium sulphide; the zinc sulphate was then frozen out. Then was tried the practice of introducing carbonic acid into a solution of calcium chloride with zinc oxide in suspension. All these and other efforts involved great difficulties in getting a reasonable amount of zinc dissolved, that depending upon many things; for instance, the soluble states in which the zinc was found. The zinc was chiefly the product of the silicate, and the zinc silicate would not go into solution with the strong acid. Having got the zinc chloride into solution, the next question was how to get it out, a problem which took some years to solve. With zinc electrodes, chlorine was apt to penetrate the liquors, particularly if zinc were deposited on iron sheets. This difficulty could be met to a large extent by depolarisation. At the time to which the speaker was referring Acheson had not worked out his method of making carbons; the carbons of those days disintegrated rapidly.

Dr. Mond then reviewed numerous incidental difficulties, particularly the avoidance of leaks, in trying to stop which he had frequently been "gassed." Again, the need for an extremely pure solution involved really new analytical methods in order to discover traces of impurity. It was easy to see that the discovery of the causes of difficulty and the question of the line of research to be adopted, requiring as it did a series of chemists working in unity, meant a great deal of hard work, and ten years were occupied in developing the process to a satisfactory point; at all events there was now little likelihood of unpleasant surprises. Formerly one unsatisfactory feature was the uncertainty of working. The speaker had also endeavoured to obtain zinc from zincate of soda. Instead of decomposing sodium in water the soda amalgam was decomposed, caustic soda being suspended. It was possible completely to obviate the production of hydrogen and obtain a deposit of metallic zinc which was not spongy. That process only became successful after years of work. With regard to the zinc sulphate processes now used he had been unable to obtain much literary information. The processes appeared to have been introduced since the speaker's last visit to the States and he had not had time to go across to find out what was being done. There was, however, no apparent reason why they should not be successful.

Dr. Mond considered that the zinc industry in this country had been kept down by the low price at which the metal was sold, attributable to the remarkably rich and cheap ores found in the Joplin district, from which it was possible to produce zinc at a low price. It should not be forgotten that, however economical the smelting process might be, the price would be regulated by the cost of getting the ore to the smelting plant. The ores of Central America could not be economically brought to this country, a circumstance which had hindered the zinc industry here. In the case of the large deposits of mixed ores in Australia, the very complicated dressing problem had taken long to work out, and was only brought to success by the flotation process, which, he would observe, owed much to the investigations of colloidal substances and their behaviour. Generally, so soon as the technical problems of dealing with the ores were settled, the question of local conditions arose. He was open to correction, but he thought that much of the detail technical work was to the credit of the Germans, and it was because they had so worked out the processes that they obtained the contracts for the working of the Australian ores. There was no reason why, however, the processes should not have been worked out in this country; only men with brains were required, and if these were few and far between, brains had, at any rate, no nationality. He considered the future of the industry would be remarkable. Much the same

course should be taken with the Australian ores as was adopted by the French in regard to the nickel ores of Caledonia, namely, the establishment of smelteries at both ends of the line to the consumer. The industry in this country had, he thought, also suffered from the fact that it was only now, at the last moment, that proper methods had been adopted for collecting and condensing the sulphuric acid fumes which had proved so grave a nuisance. One influencing factor would be how far America would be able to deal with its own huge production. America had used some of her large war profits in aggregating this great production. Who were to be the consumers remained to be seen.

Mr. H. K. Pickard desired to interject a denial of Dr. Mond's statement that the Germans had anything to do with the flotation process, which has been brought about and developed in all its details by British firms. It was only after the latter had produced the concentrates by their own unaided efforts that they sold them to Germany.

Professor Turner remarked that one of the points that had interested him very much in visiting the Belgian works some few years ago was the question of the crucibles, to which the author had referred. He had not only been interested in the mechanical appliances for pressing the crucibles, which had to some extent been adopted in South Wales, but also in the examination and testing of the clay. In England smelters were behindhand, as compared with Belgium and Germany, in testing refractory materials for the making of retorts for zinc manufacture. Full use was not made here of American methods of examining and classifying refractory materials on the lines of Tschirner, and the microscopic examination of the particles that had been sized and separated so as to recognise the different mineral constituents in the fine clays and the coarser sandy particles. He agreed that two clays of the same chemical composition might give different results, partly on account of different size of particles, and more by reason of the different character of the minerals constituting those particles; in fusibility and solubility of the alumina present the results might be greatly different. Referring to electric smelting, members would recall the contribution on experiments for the reduction of zinc in the electric furnace by Dr. Stansfield, of Montreal, who had pointed to the difficulty arising from the production of a large quantity of blue zinc, which was very difficult to use, and had only a limited application, despite the use of zinc dust in the gold industry at the present time. In a paper summarised in the "Journal" of the South African Metallurgical Society, Dr. Stansfield did not regard favourably the prospects of electrical smelting of zinc. Its application was unlikely save where current was very cheap, and even then the zinc fume difficulty would constantly be present. The vacuum processes would not seem to solve the difficulty, as a very small leak would entirely counterbalance any advantage; in practice it was not possible to prevent a small leak. With regard to the hydro-electric processes, particularly electrolysis by either the zinc chloride process mentioned by Dr. Mond or the zinc sulphate process, it appeared to be a question of the price at which a zinc could be got into solution and then the price at which it could be deposited from solution. There was no difficulty in getting a comparatively pure zinc sulphate from complex ores, the ultimate question being one of current in sufficient quantity and sufficiently cheap. The answer to this question would be in the affirmative or negative, according to locality; for localities with complex ores he foresaw a great future if the zinc could be extracted from the ores by solution and deposited in the form of very pure zinc by cheap electric current.

Dr. Rosenhain, who spoke next, desired to add to Professor Turner's observations on refractories another to the effect that the question was proving a matter of vital importance in quite a number of industries, and it was a coincidence that several industries which had flourished, particularly in Germany, in recent years, were just those requiring special attention to the character of the refractories. The optical glass industry, with which the speaker was concerned, and the glass industry generally, was largely dependent on the choice of refractories; apparently the zinc industry was in a similar position; it was therefore worth emphasising the need for a systematic, extensive—and expensive—research. The alloys of zinc and aluminium, referred to by Mr. Smith, had been a speciality with the speaker, and he would like Mr. Smith to add to his paper a reference to the "Tenth Report of the Alloys Research Committee," the mechanical properties of these alloys being there worked out. Mr. Smith's statements were in general agreement with the report. Mr. Smith had, however, said that alloys of aluminium and zinc containing more than 40 per cent. of zinc were valueless. That was partly so, but they had "tempting" properties. Such alloys, high in zinc, were used for die-casting purposes, although mostly with disastrous results; he had seen die castings from such alloys which after a few years had practically disintegrated. But the idea that zinc-aluminium alloy castings disintegrated spontaneously was not correct, certainly in the case of alloys with less than 30 per cent. of zinc and probably up to 60 per cent. of zinc. Another point. It would be a service if the speaker could impress upon representatives of the zinc-producing industry the importance of making alloys of absolutely pure zinc. This applied not only to zinc-aluminium alloys, where the presence of quite small quantities of lead seriously reduced the value, but also to copper-zinc alloys and the whole class of industrially important alloys of zinc and other metals. As an Australian, he protested against the adverse comments on the climate. Australian workers in the zinc industry were, according to his experience, perfectly healthy, and the difference in climate was not so great as was frequently imagined. In regard to the establishment of works at the two ends of the line of steamers, the Broken Hill Proprietary Company had zinc smelters on the coast of South Australia and coal mines and iron works at Newcastle. In one direction coal was carried from Newcastle and iron ore was carried back, freight being balanced in this way.

Mr. H. Kaye wished to make public, he believed for the first time, the fact that the Metall Gesellschaft, acting on behalf of the German group, purchased for a number of years the whole supply of Australian zinc concentrates, the price being regulated by the average of mean daily quotations made on the London Metal Exchange. That contract having been made with the Broken Hill and allied groups, the Metall Gesellschaft formed the Australian Metal Company. The contract was so made that if the price of spelter rose above 23*l.* any excess was to be divided between buyer and seller. The contract having been signed the European Spelter Convention was immediately formed (January, 1909). At that time spelter was 21*l.* 10*s.*, and he believed that it was common knowledge that the price was forced up to 26*l.* 10*s.* and 27*l.* per ton. The higher price brought a remarkable increase in production, so that after remaining for two years at about 26*l.* or 27*l.* it rapidly fell to 22*l.* and gradually to 20*l.* That was the history of the German acquisition of the Australian concentrates.

Mr. A. R. Lambert directed attention to certain discrepancies in the figures given by the author in relation to Japanese production of zinc at the works at Ohmula (called, the speaker said, "Ohmuta"). At the former works the production was stated to be twice that of Osaka. That was incorrect. The output in 1914 was 2,900 tons for the Ohmuta works and 5,000 tons for the works at Osaka. In 1915 the output of the Ohmuta works was only 5,200 tons—whereas the paper suggested 14,000 tons—and that of Osaka about 11,000 tons. The estimated output for 1916 was about 40,000 tons altogether.

Mr. H. M. Ridge remarked that the author had referred to Silesia as the origin of the arrangements for utilising and preventing the deleterious effects of the sulphurous acid generated in the roasting of the ore; the speaker had, however, records showing that the practice originated in one of the works at Stolberg in Western Prussia as long ago as 1868–69. With regard to American fireclays, the speaker had in 1914, just before the war broke out, instituted comparative tests of European and American fireclays, the results of which did not substantiate the belief in Germany that certain Continental clays were the best for retorts; the experiments did not show that the American fireclays were inferior. To the speaker the matter turned upon the treatment and handling of the clays. The author had referred to one or two Continental brands of spelter, but the speaker would like to point out that there was a large number of brands, many works making two or three different brands depending on the quality, mainly lead or iron contents; these were sold at varying prices. It was slightly misleading to give a few names without the complete list. The speaker attached little importance to the slight decline in the production of zinc ore in Silesia in 1913; there were probably economic reasons associated with the conservation of national resources, and several works were only producing some 30 or 40 per cent. of their capacity. An interesting circumstance in the present development of the German spelter industry was the fact that Silesia was supplying the Western German smelters with zinc ores, in spite of the distance and freights, mitigated to some extent by canal transport.

The author had referred to the tailings accumulations at Broken Hill as 300,000 tons, but 5,000,000 tons was a more correct figure. Moreover, the figure of 17 per cent. zinc for the tailings was under the mark; the speaker had himself, in 1899–1900 dealt with Broken Hill tailings containing in parts as much as 32–33 per cent. zinc. With regard to the Siemens regenerative furnaces, these were used up to 1914 by one of the principal German groups and their friends in Belgium, but the furnaces which were superseding them in Germany were of the counter-current recuperative type, and this development was now proceeding with special rapidity in Silesia, owing to the high prices of coal and the consequent need for fuel economy. With regard to the size of zinc retorts, referred to by the author, the speaker considered the 8-in. charge thickness as too high; it was impossible to reduce the zinc oxide even at 6 in., and lesser dimensions had to be used to get the heat units into the pot. Mr. Smith had alluded to the large loss of zinc in roasting; the speaker had not had that experience, and had found flotation concentrates easier to roast and more convenient to handle, subject to their not being allowed to "lump." The speaker agreed with Mr. Smith's view that as regarded the cleaning of retorts the machinery used was not so far satisfactory, but in respect to mechanical charging machines he knew of three Continental firms who had used them with highly satisfactory results, some reduction of cost being also effected. The author had quoted a brand of virgin spelter as containing 2.55 per cent. of lead, but the speaker's experience had been that 2 per cent. of lead would produce globules, and that lead would be certain to settle out at the bottom of the ingot. Such an analysis was decidedly unfavourable as the bulk of the English spelter was much better than that.

Mr. Ridge disagreed with Dr. Mond's views as to the competition of the Joplin ores. Even if American smelters were willing and able to rely on domestic ores, they could not in ordinary times ship spelter to England commercially. Prior to the war, England had been producing a noticeable amount of high-grade metal; he referred to the practically pure metal, made by distillation, for the production of high-grade brass. The owners of the works were, however, told that it was more desirable that they should produce common spelter to be refined abroad, and an entirely British industry had, for the time being, been stopped. In making cartridge cases a metal practically free from lead was necessary, and the speaker asked why that matter had not been tackled in this country. In 1914 France did not produce an ounce of high-grade zinc, but was now producing a large tonnage. Apart from the needs of the war, brass makers, once having learnt the use of high-grade zinc for brass-making, would continue, on the ground of its high economy, to use it after the war.

Mr. Ernest A. Smith then replied briefly to the discussion. Firstly, in introducing Professor Bacon's remarks into the paper, he should have added that these remarks referred almost exclusively to American ores; and, as he had pointed out, American practice was behind European and

Australian practice in respect to ore concentration. Mr. Pickard was an authority on flotation of ores, and the speaker regretted that his ambiguity should have led that gentleman to suppose he had suggested that the process produced a lot of slime; he had not meant to say so.

Several speakers had referred to clays, and Mr. Smith agreed with Dr. Rosenhain that more attention would have to be given to this matter. He believed that the gas works people had taken in hand the question of refractory materials, and were doing useful work, much of which would be applicable to the spelter industry. It was not, however, altogether a question of chemical composition; the physical condition of the clay was also of vital importance. Attention had been drawn to the hydrometallurgical processes, and, in this connection, he would urge that it was very difficult, in a paper covering so much ground, to give further details of these processes; personally, he believed they had a future before them. Moreover, the details had been ably discussed in a paper by Mr. Ingalls, to which he (the speaker) had referred. As to purity of zinc for alloys, he felt that there was much research work to be done in connection with metallurgical industries, and the production of pure metal. Such work had shown that the presence of even small quantities of impurities had marked effects when metals were used for alloying purposes. The speaker regarded Mr. Kaye's remarks as valuable, such information being rarely published. He confessed to more or less ignorance in regard to the Japanese zinc industry, and if the figures he had given were incorrect the inaccuracy was due to the source of his quotation, namely, "Mineral Industry." In reply to Mr. Ridge, the speaker had not attributed the original utilisation of the sulphurous acid generated in roasting zinc ore to Silesia; what he had indicated was that the practice of using the gases for the manufacture of sulphuric acid had been adopted by the Silesian smelters in common with others. With regard to the analyses of brands of spelter, he had merely quoted those given by Mr. Primrose, because they had already been brought before the Institute of Metals, and, so far as the speaker knew, these analyses of spelter were the most recent; he agreed that the percentage of lead was much above the normal for ordinary English brands.

A vote of thanks having been accorded to Mr. Smith for his paper, the President announced that the paper entitled "Cadmium in Spelter," by Mr. W. R. Ingalls, would be taken as read. We published this in full in our last issue.

The proceedings terminated with votes of thanks to the Chemical Society for the use of the meeting room, and to Mr. Ingalls for the paper just mentioned.

THE LATE MR. RICHARD PRICE-WILLIAMS.

As announced briefly in our last week's issue, Mr. Richard Price-Williams died on the 19th inst. at the age of 89. He was the son of Dr. John Morgan Williams, of Bridgend, Glamorganshire, and was born in London in November, 1827. Mr. Price-Williams served his pupilage under the late Mr. George Heald, M. Inst. C.E., who was the late Mr. Thomas Brassey's engineer in charge of the construction of the Lancaster, Carlisle and Caledonian Railways, in the 'forties of last century. He afterwards entered the locomotive works of the firm of Messrs. Kitson, Thompson and Hewitson (now Kitson and Co., Ltd.), of Leeds, as an apprentice, being, later on, from 1854 to 1860, engaged in the designing and construction of girder bridges and other civil engineering work as assistant and resident engineer on the Great Northern Railway, at Leeds. He acted afterwards in the capacity of consulting engineer in the construction of the Metropolitan Outer Circle Railway, and in the preparation of plans and estimates for a number of other railways, both in this country and in the Colonies.

Mr. Price-Williams' name will always be intimately associated with the introduction and the development of the Bessemer process in this country. His early connection with the construction of railways briefly alluded to above had led him to make railway engineering his own particular branch from the very commencement of his active practice. As early as 1866 he read before the Institution of Civil Engineers a paper on the "Maintenance and Renewal of Permanent Way," which was followed, four years later, by a further paper on the "Maintenance and Renewal of Railway Rolling Stock." These papers, especially, perhaps, the former, and his continued personal efforts, were greatly instrumental in inducing the British railway engineers to, at least, make a trial of the Bessemer steel rails in place of the iron rails used until then and which were so short-lived under heavy traffic. It may indeed be said that Mr. Price-Williams, who was primarily a railway engineer, and who, as such, would have carried all the responsibility, in case of failure, of any new departure recommended by him in permanent way construction, was quicker to discern the future of Bessemer steel rails than the British metallurgists themselves.

Sir Henry Bessemer was not long in recognising the advocate he found in Mr. Price-Williams; he greatly appreciated his services, and appointed him the manager of the first Bessemer steel works put down at Greenwich. It may be mentioned here that the first piece of Bessemer steel was made at Baxter House and then rolled into a rail-shaped bar at Dowlais. The chemical tests of this bar were made by the late Mr. Riley in 1857, at which time Mr. Price-Williams was assistant engineer on the Taff Vale Railway, where he had full opportunity to witness both the manufacture of iron rails and the very small early preliminary researches in the matter of Bessemer steel.

At a later date in his career Mr. Price-Williams designed and erected a Bessemer converter plant and a rail mill at the works of Mr. Samuel Fox, at Stocksbridge. When this was completed and could produce steel rails, most of the railway companies in the country were still unconverted and declined for many months to consider their use. Hence the paper above referred to read by the subject of this brief memoir before the Institution of Civil Engineers. After the reading of the paper in question, Sir John Fowler, the President of the Institution at the time, informed the author that the most convincing chemical tests and the admirable physical tests yielded by the new material had entirely disposed of the unfounded notion of its brittleness, and had completely established its remarkable strength and endurance.

Mr. Price-Williams was a member of the Institution of Civil Engineers since 1861, and that Institution awarded him the Telford gold medal in 1866, the Watt gold medal in 1870, and the George Stephenson gold medal in 1902. As stated in our short note last week, he had recently been nominated an honorary member of the Institution of Mechanical Engineers, an Institution of which he had been an ordinary member since 1859. He was also a member, since 1871, of the Iron and Steel Institute; this Institute awarded him, in 1898, the Bessemer gold medal. He was indefatigable in advocating the use of steel rails and in demonstrating their value before this latter Institute also, as can be gathered from his papers "On Iron and Steel Permanent Way," read in 1881, "On Steel Permanent Way," read in 1898, and by his numerous contributions to discussions on these subjects. He, further, contributed to the Iron and Steel Institute, in 1909, another interesting paper in which he compared in detail the life and the cost of renewals of permanent way on a large number of railway lines.

The high reputation which Mr. Price-Williams had acquired as a railway engineer led him to be appointed by the Government of New South Wales in 1889, and again in 1895, to report upon the conditions of the railways in that Colony. He was also retained, in 1889, by the Tasmanian Mautine Railway Company to examine that railway and to give evidence before the Judicial Court at Hobart in favour of the payment to the company of annual subsidies. He obtained a verdict in favour of the company, who, later, appointed him arbitrator in the matter of the disposal of the railway to the Tasmanian Government; he was subsequently appointed consulting engineer by the Governor.

Quite apart from his engineering activities, Mr. Price-Williams did a large amount of statistical work on a variety of subjects. He at different times read papers before the Royal Statistical Society on coal, on the population of England and Wales, on the population of London, on railway rates and charges, &c., all of which are of real interest and usefulness, but his principal work will always remain that which he carried out in connection with railway construction, and he will long be remembered with affection by a wide circle of metallurgical and engineering friends as "Permanent-Way Price-Williams."

THE IRON AND STEEL INSTITUTE.

AFTER the proceedings at the meeting of Thursday, the 21st inst., referred to on page 289 *ante*, the first paper taken was one contributed by Dr. J. E. Stead, having the following title:—

INFLUENCE OF SOME ELEMENTS ON THE MECHANICAL PROPERTIES OF STEEL.

It was read in abstract by the author. The paper is an extensive review of the influence of carbon, phosphorus, sulphur, manganese, silicon, copper and tin upon steel, and gives a definition of mechanical properties. Dr. Stead gave the mechanical properties of pure iron, after allowing for the influence of the small amount of carbon present in the purest commercial soft steels, the figures in the paper—approximate only—being based upon the calculations made by Professor Arnold, Mr. Harbord and others; he expressed the hope that exact figures would be established. He suggested that the only way to arrive at reliable figures as to the influence of elements was by having the steels normalised under identical conditions. He quoted the average mechanical properties of normalised steel containing less than 0·9 per cent. of carbon. Among his examples was one to the effect that widely varying results are obtained with the same steel if it is rolled into plates of varying thickness, in which the more work at the lower finishing temperature the higher will be the tenacity. In order to get the same static tests in ship plates of varying thickness, the carbon had to be higher in the thicker plates. The paper dealt at length with the heat treatment of carbon steels conducted by different scientists and gave the results obtained by each.

In the matter of phosphorus it would appear, the author stated, that the effect of 0·1 per cent. of phosphorus, within certain limits, was comparable with that of carbon. The effect of carbon was greater than that of phosphorus in reducing ductility. Phosphoretic steel was still largely used. Phosphorus was most useful in small amount in tin-plate bars, as it prevented the sheets from sticking together during rolling; it conferred the important property to steel of giving clean and bright surfaces when turned, and, moreover, increased the elastic limit and tenacity. Dr. Stead added that he was not agitating in favour of high phosphorus steels; it was necessary, on the contrary, to eliminate both sulphur and phosphorus. There were times, however, when both were an advantage. If the conditions of testing and the work to be done justified a higher percentage of phosphorus, and if all the necessary mechanical properties were met, then the material containing phosphorus should be taken. In short, in judging the quality of steel, it should not be assumed that phosphorus was as invariably bad as it was painted.

The bad character of sulphur was earned in the early days of steel-making owing to the difficulty of getting a sufficient quantity of manganese into the steel without unduly raising the carbon. The work of Brinell had shown that steel with 0.15 per cent. of sulphur gave better impact tests than any other steel used in a most exhaustive series of tests, better far than similar steel containing only 0.015 per cent. of sulphur. Steel high in sulphur when rolled to small sections resembled wrought iron and was more or less fibrous. Sulphur, then, might be regarded as a friend when used intelligently and not invariably as the enemy it was represented to be, and this applied with special force in the cast-iron foundry.

In regard to silicon, the evidence as to its effect was somewhat variable. Up to 0.7 per cent. its effect was not very pronounced, either one way or the other, and it was doubtful whether any difference could be detected in steels varying in silicon between

0.05 and 0.30 per cent. Silicon produced soundness in cast steel, and on that account was now largely used. Owing to silicon, basic steel now approached more nearly in good general properties to acid open-hearth steel, if it had not already surpassed it. At one time silicon was considered bad and was ruled out; then Mr. Sandberg introduced his silicon steel rails, which were found of greatly improved quality. Sir Robert Hadfield had stated that, on the average, silicon up to 1.75 per cent. increased the yield point and tensile strength, but did not impair the ductility; beyond that point, increase of tenacity was only obtained with a serious loss of ductility, and that statement now represented the accepted truth.

Copper for more than two generations had had a very bad name owing to the mistaken observations of certain investigators. Even to-day one came across steel specifications in which copper was barred, and these could only be regarded as an indication of the ignorance, if not stupidity, of those who prescribed the composition of new steels, for it had been proved long ago that copper in steel, instead of being an evil, was quite harmless and was sometimes distinctly beneficial. Here Dr. Stead asked the meeting to give the result of their experience in the matter of the welding properties of steel containing copper. It was surely time that prejudice against copper should be abandoned. Cupreous iron ores were really excellent for steel-making and the day was not far distant when we should be prepared to pay a higher price for them.

In the matter of tin, Dr. Stead stated that 55 per cent. of detinned scrap was used in one of the Clarence open-hearth furnaces with 45 per cent. of molten iron. The ingots obtained from the cast could not be rolled, the steel being exceedingly hard; an analysis showed this to contain 0.75 per cent. of tin. The tin increased the yield-point and maximum stress and decreased the elongation and reduction of area.

The discussion was opened by Mr. M. Mannaberg, who said he felt sure the members were greatly interested to hear the remarks concerning the influence of sulphur and phosphorus on steel. The fact was well known to all steel-makers that phosphorus was not so great an enemy as it had been stated to be. But the steel was ordered from the steel-makers, who were not at liberty to produce what they liked, and in steel required for shell manufacture, for example, the steel-makers were compelled to see to it that the percentages of sulphur and phosphorus were less than what they thought the necessary figures. Steel-makers had also known long since that copper was not injurious, and endorsed all that the author had said with reference to that element.

Sir Robert Hadfield, who followed, found the paper a most thorough one, and in that respect it was like all the work carried out by Dr. Stead. He (the speaker) called attention to Dr. Stead's quotations defining annealing, and found that the word "annealing" was getting played out. It either covered too much, or did not constitute a sufficiently complete definition of the treatment followed. According to the dictionary, the word came from the Anglo-Saxon *an* and *ælan*, to set on fire, to burn. It was preferable to use more specific language, that is to say, to indicate temperature, time, and size of mass being heated. No comparison could be made between the process in the case of a small mass and in that of a large one. The German term for the verb was *ausglühen*, and in that respect was perhaps not better than ours, whilst the French *recuire* might be preferable. He hoped Dr. Stead would be able to suggest a term better describing the object of annealing. In one of his examples of carbon steel, containing 0.3 to 0.4 per cent. of carbon, test bars heated to 925 deg. C. and cooled in ashes had a maximum stress of about 40 tons per square inch, with an elongation of 24 per cent.; the bars, after reheating to 875 deg. C., quenching at that temperature in water at 28 deg. C., and tempered in molten tin at 525 deg. C., showed a maximum stress of about 50 tons and an elongation of 10 per cent. (the pieces were destined to resist sudden and violent compression by shock). He Sir Robert) would have liked to see the yield-point given, together with the stress and elongation, for the yield-point was most important and an excellent guide. Plain carbon steel required to have a high maximum stress, and an elongation not less than 22 per cent. was difficult to obtain in a large mass; the mass cooled slowly and elongation was not uniform, but the heat treatment allowed all the conditions to be met.

In regard to the effect of phosphorus, he (Sir Robert) did not agree in all points with Dr. Stead. With mild steel the percentage of phosphorus could be higher, and, as Dr. Stead had pointed out, when ferro-manganese could be obtained at a reasonable price, its use meant lower carbon. Then one could have a higher percentage of phosphorus in the steel, but the procedure was not safe, and the statement should be qualified more than it was. Steel with comparatively high percentages of sulphur and phosphorus was more liable to be burnt in the heat treatment, owing to the too large crystallisation, than steel with lower percentages of these elements. One could obtain excellent results by quenching and reheating, and thus remove the effect of overheating, but unfortunately phosphorus had the tendency to increase the size of the crystals, when brittleness came in. He did not think the risk should be run of raising the phosphorus beyond limits. Phosphorus in the steel for armour-piercing shells was detrimental.

Mr. C. H. Ridsdale expressed the opinion that Dr. Stead's paper was one which had long been needed. He (the speaker) had never advocated laxity in the matter of the percentages of the elements in steels; he had for many years carried out experiments with various classes of steel and had long found that prevailing ideas as to the harmfulness of elements contained in some of them were greatly exaggerated. Such was the case, for example, with copper, and in regard to this element it was difficult to get at the real true source of the trouble; it was considered simply, in many cases, as a scapegoat, with the direct result that further research concerning it was put an end to. Faulty treatment came into play also and had to be taken into account. (Here the speaker showed several of his specimens of phosphoretic steels, pointing out how well they had stood the bending tests and shearing.) He concluded by stating that sulphur and phosphorus should no longer be considered as impurities but as elements of steel alloys, and, like all other matters in all walks of life, should be used judiciously.

Professor Arnold, who followed, stated that Dr. Stead's contribution should be classed as a book. It contained most important data and many interesting points were dealt with which would repay careful reading. The main features were those which covered sulphur and phosphorus, and valuable papers on these elements had already been contributed to the Institute by Dr. Stead, Mr. Harbord and Mr. Ridsdale. What was wanted was to keep a balance in these matters; this did not obtain at the present time, for many munitions manufacturers were working under most unreasonable Government specifications. If, for instance, the specification required 0.04 per cent. of phosphorus, and there were 0.042 per cent. or 0.038 per cent., the material was rejected; this was most unfair, and had for effect to restrict output in this country in a most ridiculous way. Dr. Stead had tested phosphoretic steels under alternating tests, and his results confirmed those obtained at Sheffield University where it was found that the ratio was 33 for the one having 0.50 per cent. of phosphorus, that having 0.94 per cent. being 100. He (the speaker) thought that when phosphorus was below 1 per cent. there was no danger in the case of structural steel. In the matter of copper, Professor Arnold was quite in accord with Dr. Stead and he regretted the absence of their past president, Dr. Cooper, who would also confirm the point. In this connection he added that when a silly error crept into a text-book, it took at least 20 years to get rid of it. The contention that copper caused cold shortness and red shortness was absolutely futile. Dr. Cooper would have been able to state that years ago he had an offer for 700 tons of iron ore at a low price because it contained 0.50 per cent. of copper; he transformed this into pig-iron and then into steel rails in the acid Bessemer converter, the steel in the rails averaging 0.47 per cent. of copper. All the rails passed the inspection and a record obtained 17 years later showed that there was not one single failure. A graduate of Professor Arnold's went to America on one occasion and obtained a berth in a company there, one of his duties being to ascertain why that company's rails were better than those of all other companies. He stated later to Dr. Arnold that the secret of the rails made by the company in question was that they were made from particular ores which were found to contain an average of 0.50 per cent. of copper. Copper was not an impurity at all.

Mr. E. H. Saniter stated that the Institute owed a debt of gratitude to Dr. Stead for his valuable contribution, adding that work of this kind was most valuable and useful. Dr. Stead had stated that the practical definition of the yield-point was the load per square inch at which a distinctly visible increase occurred in the distance between the gauge points on the test piece, observed by using dividers, amounting to more than 1/200 of the gauge length. With this, he (the speaker) agreed. Unfortunately in the works they were not faced with one single practical definition; it would, therefore, be of great advantage if, together with the engineering firms, a definite limit could be fixed, and also a definite manner in arriving at the yield-point. Standardising in this matter was required. The author had also referred to the results obtained by Dr. Baker, his (the speaker's) assistant, to determine the effect of normalising steels containing from 0.45 to 0.68 per cent, of carbon. The utmost care was taken in ascertaining the yield-points of these steels, and the difference did not exceed five-thousandths in 2 in. The use of the word "tempering," as being a reheating after quenching, should apply to the heating to all temperatures below the recalescence points. In regard to "normalising," this had become the designation of a process, whereas originally the word was used to qualify the result produced. All these terms and the processes varied with the different authors; it was not remarkable, therefore, that the results obtained varied also. In regard to phosphorus, Sheffield did not believe much in it; whilst sulphur was not an unmitigated friend, and its presence in steel rails might cause cracks leading to split heads. The fears as to the presence of copper in steel were absurd. He (the speaker) was glad to have the information given in the paper concerning the action of tin; he had experimented with steel containing 0.35 per cent. of tin, and the steel rolled fairly well.

Sir John Randles, who followed, expressed the opinion that it was necessary to receive with caution the statements as to the good effect of sulphur and phosphorus generally. He emphasised the point that the suppliers of coke, ore and limestone had had their special attention called to the danger of these two elements, and if they understood that the danger had been exaggerated, the troubles of the steel-makers might increase.

Dr. Rosenhain said that progress in metallurgy was very rapid and knowledge was not disseminated as widely as it ought to be. The author's paper, in this connection, was a most important one. He (the speaker) called the attention of the meeting to the report recently issued by the Standards Committee on automobile parts and to the nomenclature of tests it contained, which was a compromise arrived at between various manufacturers. He thought that nomenclature should be adopted. The author had largely relied upon the data of mechanical tests; the tests should be exhaustive, and one very important test was the notched bar impact test, which was valuable in the results it could give in relation to some of the constituents referred to by the author. The latter would find, said Dr. Rosenhain, that the results it gave would not quite bear out those of ordinary and drop tests. Actual records should also be kept of the behaviour of material in actual service, and all results should then be correlated. In the matter of sulphur and phosphorus there was a general consensus of opinion that these elements were dangerous beyond certain limits.

In the course of a few brief remarks, Mr. F. W. Harbord thought the author had looked into the matter more from the point of view of the static test, which did not throw out the full effect of phosphorus. In the Wohler test, when all specimens were tested under the same stress, they all

varied in elastic limit. Sulphur and phosphorus were positively dangerous from the student's point of view. Dr. Stead had quoted one of Professor Howe's statements only and, besides, Professor Howe might now modify his former statements in regard to the effect of phosphorus in steel. He (the speaker) quite agreed with Professor Arnold's statement to the effect that what was wanted was an intelligent interpretation of specifications. There were so many variables which came into play that a certain latitude should be allowed. Nevertheless, the less phosphorus and sulphur we had the better, and in regard to phosphorus there always was the risk that it was higher in one part of the ingot than in another. With sulphur one was liable to have incipient cracks, then the material broke in the cracks. Phosphorus to prevent stickers in sheet rolling was good, but it was detrimental in the manufacture of deep stampings.

Mr. C. J. Bagley also disagreed with Mr. Stead in his statements concerning sulphur and phosphorus, and stated that thousands of trials would yet be required to decide the points.

Dr. Stead, who replied to the discussion on the following day, Friday, the 22nd inst., stated that the yield point inquired about by Sir Robert Hadfield was between 35 and 40 tons. He wished particularly to draw attention to the course which the discussion had taken. He had never once mentioned in his paper the word "shell." He had never advertised high sulphur and high phosphorus steel. He had simply said that for certain purposes phosphorus may be useful and sulphur may be useful also. Certain steels were sold with properties which could only be conferred on them by the presence of these elements. He repeated that he had not referred to shells, but as some speakers had done so in the course of the discussion he perfectly agreed that the said elements in certain circumstances might be a source of danger. No evidence, however, had been brought forward to show that a slight percentage of sulphur and of phosphorus would cause the shells to fail in the gun. At the beginning of the war sulphur was restricted to 0.04 per cent. in all shells, and it was stated that these would be liable to fail if the proportion was raised to 0.06 per cent., but thanks to the efforts of Sir Robert Hadfield, the limit was raised to the latter figure, and this raising of the percentage of sulphur had not made the slightest difference; shells did not fail more in the gun now than they did formerly. Greater care was exerted now in all directions and there was less risk now than when the maximum allowed was 0.04 per cent. He (Dr. Stead) had never said that sulphur and phosphorus were an advantage, and he did not say so then, but people now knew that the raising of the figure to 0.06 per cent. had no evil effect. He had always been very careful to point out that steel for armour-piercing projectiles had to be made most carefully; he agreed that that steel should be as pure as possible. But he asked why, after the long experience gained with non-hardened steel for land guns, the Government would not allow the use of non-hardened steel for naval purposes. America allowed it, with 0.06 per cent. of sulphur and of phosphorus, which pointed to the fact that we in this country made the advances and other people took advantage of them. He asked Sir Robert Hadfield to continue his good work in the same direction, to use his influence to advocate the presence of 0.07 and 0.08 per cent. of sulphur and of phosphorus in the steel, and to advocate also trials with shells made from steel having elements above the limits now prescribed, but having also all the required physical properties. He (Dr. Stead) had advocated these points, but he had been put down as an outsider, as an interfering crank for daring to suggest to the authorities that they could have other specifications than the present ones, and nothing had been done. The absence of any true spirit of research had cost the nation thousands in the past, and unless our methods were improved upon the nation would have also to pay thousands in the future. In his speech at the recent British Association meeting the President of the Engineering Section had stated that the armour combine had at first restricted the output of shells; he (Dr. Stead) hoped this would be denied; they may or may not have prevented others from entering the lists, it was for them to say. It was whispered that an influence of the same kind was carried on to-day also; it was, again, for them to disprove, but he suggested that if we were absolutely free from that kind of interference, every influence should be used to induce the Government authorities to make a trial of material rejected by chemical analysis, but which had every one of the physical properties. Dr. Stead added he had been told that because acid steel-makers had trouble in obtaining sufficient pig-iron low enough in sulphur and phosphorus, they had raised the limit in the steel to 0.07 per cent. He, on the other hand, did not recommend a change in the percentage of these elements until the effect of raising the limit was tried. Before the increase of 0.04 to 0.06 per cent. referred to, therefore, instead of fighting with "silver bullets" we had been fighting with "golden shells." The Germans were putting somewhat more sulphur and phosphorus in their shells than we. Let the steel-makers, added Dr. Stead, and the Admiralty correlate results and try various qualities, having in view the benefit of the country, for by having such unnecessarily drastic specifications we were greatly restricting our output. In reply to Mr. Bagley, the trials he referred to had already been done and work could be carried out on their basis. Mr. Saniter had referred to ghost lines which could not be said to be superficial or to go down to a certain depth; an undue proportion of sulphur must be the cause. Dr. Rosenhain had said that the physical tests should all be thoroughly correlated; he (Dr. Stead) agreed fully with him on this point, for with variety in the tests the results were not fair. The time would come when we should need to go through the effects of all the elements in iron, to go through also every test in every sample so as to obtain accurate knowledge. He (Dr. Stead) had once told Sir Alexander Rendell that if he brought back from India specimens of the steel rails which had done the best service he would find that they were not according to specification. Sir Alexander never brought any back. The Engineering Standards Committee, in view of the drastic specifications, had decided to increase the sulphur and phosphorus in rails to 0.07 and 0.08 per cent.; this had not resulted in the fracture of rails. The fracture of rails was independent of the chemical composition of the steel, but segregation might come in and tend to cause fracture. The class of work which would be most adapted to the National Physical Laboratory would be the investigation of steel rails both in this country and abroad, and the Laboratory should be better supported by the country than it was at present. He was glad that Professor Arnold had given valuable information concerning the influence of the presence of copper in steel, and hoped that those specifications which prohibited the presence of copper in steel for general use would be deleted so as no longer to hamper the production of good steel. Steel containing copper corroded much less rapidly than steel which contained none. Mr. Saniter had made a valuable suggestion to the effect that normalising should refer to a heat treatment to a determined temperature followed by a cooling in air. The size of the piece should be given also. Sulphur, whether in acid or basic steel, would equally lead to sulphur lines. The amount of sulphur was a measure of the manganese sulphide. He (Dr. Stead) did not see why 0.07 per cent. of sulphur should not be allowed in basic as in acid steel; it had no more evil effect in that than in another steel. Sir John Randles thought that he (Dr. Stead) advocated laxity in the specifications; nothing of the kind. He was independent, and in acting as umpire he had occasionally to award penalties should the sulphur and phosphorus contents of a material exceed the limits prescribed. Hematite pig makers had to have ores with low sulphur and phosphorus, for their pig-iron was destined to be used for all classes of manufactures, guns included. Sir John should therefore see that he (Dr. Stead) did certainly not want to make the specifications less drastic for the benefit of steel-makers. What he wanted, on the other hand, was to prevent Government from spending money on unnecessary conditions. Mr. Harbord was of opinion that anybody would say that he (Dr. Stead) was advocating high phosphorus. That was not the case. He did not at all advocate doubling a percentage; he advocated, on the contrary, a gradual increase, then testing in every way and afterwards the taking of a decision. He (Dr. Stead) could not get the authorities to grasp the reasonableness of so proceeding—a child would recognise it. In regard to his statements from Professor Howe's work, he (Dr. Stead), as would be seen, had been most careful to obtain all the evidence and not to satisfy himself with general statements. He challenged that 0.06, even 0.09, per cent. of phosphorus was harmful in a shell that had not been heat-treated and hardened. He added that he held no brief for the basic steel-makers of Middlesbrough, but he would say that they could make as good steel as that of the acid steel-makers of Sheffield, and their steel was going to take an important place in the markets in the future. Many members had read in the paper points that did not exist in it. Physical and mechanical tests must be the final appeals, and he believed that if the matter of shell specifications were placed in the hands of the Engineering Standards Committee there would be much less trouble than there was now. The statements he had made would have to pass before the censor and if they were censored the interests of the nation would not be served.

On the motion of the Chairman, Dr. Stead was awarded a hearty vote of thanks for his contribution.

(To be continued.)

NOTES.

THE IRON AND STEEL INSTITUTE.

With reference to the scheme for the proposed reorganisation of the Iron and Steel Institute outlined at the meeting of Thursday, September 21 (see page 289 *ante*), a scheme which Sir Robert Hadfield recently submitted to the Council at various meetings, Sir Robert writes that it is very desirable that the Institute should provide every possible facility for expansion both on the scientific and on the technical side, in view of the importance of the future development of the science of metallurgy and the probabe large forthcoming increase in the manufacture of iron and steel in this country. In one of the recent council meetings of the Institute Sir Robert stated that another reason for considering the scheme was the fact that the various institutes representing our American competitors were now commencing to reap the benefits of their wise policy of having the whole of the work they undertake concentrated in one building, one library and one club; in other words, America had now one common centre for its Technical Institutes, with all its consequent advantages to the metallurgist and mining, mechanical, electrical and civil engineer, including saving of time, better organisation and better work. In view of the desirability of taking the necessary steps to meet the more intense competition likely to come from America in the near future, it was all the more important that this subject, added Sir Robert, should receive full and serious consideration by the Council. His reason for setting forth these suggestions was that whilst there was no wish to propose that local effort in any part of the Empire be interfered with, it was nevertheless high time that we should try to weld together the technical members of the British Empire on lines similar to those adopted by our American *confrères*, who had set us an admirable example of how to bring together some 26,000 different members having the same aims and ideas in one centre. Owing to the fact that certain technical institutes in this country have their own buildings, if it was objected that these could not be changed, Sir Robert pointed out that at any rate such a scheme might be considered as regards the Iron and Steel Institute, the Institute of Mining and Metallurgy, the Institute of Metals, the Institute of Mining Engineers, and some others. The different points in connection with the scheme were considered by the Council, hence the recommendations referred to on page 289 *ante*. It was also recommended that the Iron and Steel Institute should lead the way towards a closer relationship between itself and several strong local institutes, namely, the Staffordshire Iron and Steel Institute,

the Cleveland Institution of Engineers, the Sheffield Society of Engineers and Metallurgists and the West of Scotland Iron and Steel Institute, whose objects all coincided with those of the Iron and Steel Institute. In sending us the above information, Sir Robert included an interesting table showing the various British and American societies and giving the number of committees in each. The table indicates that the American Institute of Mechanical Engineers have no less than 57 committees and special committees, followed by the American Institute of Mining Engineers with 46. We fully approve the recommendations put forward by the Council of the Iron and Steel Institute and feel confident that they are of a nature, if followed up, greatly to benefit the British iron and steel industry in all its branches.

INDIAN FORESTS.

The Kulu division of Indian forests is one of the most important, as it contains the largest area of deodar-producing country under the control of the Anglo-Indian Government. The deodar is by far the most valuable tree which grows on the hills, as it provides a large part of the sleepers laid on Indian railways. It occurs throughout the north-west Himalayas, but most of the deodar forests are in native States. Some of the State forests are leased to the British Government, such as those of Bashahr State and Tehriljarhwal; but most of them are entirely under the control of the States to which they belong, as, for instance, those of Kashmir and Chamba. The Kulu Valley consists of the upper reaches of the Beas; but in addition to Kulu proper the division contains a large tract of country known as Suraj, which extends from the Beas to the banks of the Sutlej. It is an enormous tract of country, of which, speaking generally, only the lower valleys and warmer slopes are cultivated, while the upper slopes and many of the side nullahs are wholly forests. On the lower elevations, up to 5,000 ft., these consist of the Chil pine, above which comes the deodar, in places mixed with the kail or blue pine, which also occurs as pure forest. On the higher elevations and colder aspects the crop changes to fir, either the Himalayan spruce or the silver fir. The Kulu division is interesting as it is the first place in India where any attempt has been made to manage the deodar forests owned by the Indian Government under a regular system such as is practised in Europe. This system is at present in an experimental stage; but under a new working plan it will be introduced as the principal method of working the forests in the division. Trees cut down are not re-planted, it being the aim of the forester to make his fellings in such a way that trees left on the ground will themselves sow up and re-stock the area felled over. The Kulu forests at present yield a net revenue of 10,000*l.* a year, and when the new system has been developed for a number of years and the crop which is at present coming up reaches maturity, it is estimated that deodar forests will give an annual return of upwards of 60,000*l.* But the deodar forms only a comparatively small portion of the Kulu forests. There are thousands of acres of fir forest, at present untouched, which will be gradually brought under systematic working. The fir is not a valuable tree at present, the market price of a matured tree being only about 7*s.*, but it is highly probable that in the next few years means will be introduced for creosoting fir timber so that it may be rendered suitable for railway sleepers. When this object has been attained the value of the fir will greatly increase.

WATER-HAMMER.

Last winter* we noticed the researches by Mr. Charles Camichel on water-hammer. In a further communication, presented to the Paris Académie on August 7, he points out that it is important to know whether hydraulic conduits are or are not free of air pockets, and he shows how this can be ascertained. He had demonstrated that the velocity a of the propagation of a wave in the conduit can be determined by rapidly opening a valve at the end of the pipe and thus suddenly reducing the pressure there. When the value found for a agrees with the formula of Allievi, the pipe will be free of air. In the graphs of Camichel l is the length of the conduit, y_0 the static pressure at the lower end, ϵ the velocity of the water, y_1 the pressure at the extremity of the conduit at the moment 0 of maximum depression, and y_2, y_3, &c., are the corresponding pressures at the moments $2l/a$, $2 \times 2l/a$, $3 \times 2l/a$, &c.; then $y_1 = y_0 - a\,\epsilon/g$; $y_2 = y_0 + 2\,a\,\epsilon/g$, $y_3 = y_0 - 2\,a\,\epsilon/g$, &c. The depression wave thus returns to the lower end with doubled magnitude and changed sign. From the fact that the wave is reflected with changed sign by an air pocket, the position of the pocket can also be determined, somewhat as Joukovsky had previously indicated. The state of a conduit can further be tested by completely closing the pipe for periods shorter than $2l/a$. The water-hammer provoked by instantaneous closing is, moreover, transmitted at full magnitude all along the pipe, whilst in the presence at the lower extremity of an air pocket—sufficient in volume to render the compressibility of the water and the dilatation of the pipe negligible—the water-hammer will show a linear distribution along the pipe. An example will make this statement clearer. An iron pipe, 105.27 m. in length, 80 mm. diameter, 5 mm. uniform wall thickness, was provided with two pressure gauges, the one, A, being placed at one-third the length from the lower extremity, the other, B, at this extremity; the water pressure at A was 13.5 m., that at B 16.0 m. By suddenly closing the pipe a water-hammer was produced, and B registered a pressure of 21.6 m. and A a pressure of 21.5 m., nearly the same high value. In a second experiment the same pipe had at its lower extremity an air pocket of 6,600 cub. cm. volume; sudden closing then set up a water-hammer which had very different values at different points, the two gauges recording at different moments the following pressures, measured in metres:—

B	...	+ 3.18	− 2.33	+ 2.65
A	...	+ 1.06	− 0.73	+ 0.93
Ratio		3.0	3.18	2.86

One must remember that instantaneous closing of a pipe free of air (experiment 1) sets up extremely dangerous pressures in the pipe above the valve, whilst the pressure surgings are weak when an air pocket is provided at the lower extremity (experiment 2). For this reason the resonance experiments made with the aid of a valve turned by a motor (described in a previous Note) for the purpose of investigating the wave periods should not be attempted, except in the laboratory.

* See ENGINEERING, February 11, page 141.

FLIES AND BLUE-GLASS WINDOWS.—As the fly danger is so much discussed now, we may refer to a suggestion thrown out by Messrs. C. Galaine and C. Houlbert in the Comptes Rendus of July 31, 1916. Galaine and Houlbert experimented in a room provided with windows turning about horizontal axes. When the windows were open the flies flew into the sunlit room; the windows were then closed, and the flies became restless, but quieted down soon. On re-opening the windows the flies escaped. That was so with blue and violet and also red glass, less so with green windows; in a room with white, yellow or orange windows, the flies seemed to be at ease. When the blue windows were placed obliquely, so that the light inside would look blue from the outside, hardly any flies entered. The conclusion drawn is that only white, yellow and orange rays are light to the fly, the other colours being dark to them. If, therefore, rooms, especially in hospitals, sweet-shops, &c., were provided with louvres of light blue glass or with coloured bead blinds, the light could enter, but the flies would keep out and try to escape again if they had come in.

MINING MACHINERY.—The exports of mining machinery from the United Kingdom have not been badly maintained this year, there having been a considerable colonial demand. The value of the exports to South America to July 31 this year was 13,447*l.*, as compared with 10,189*l.* and 29,064*l.* in the corresponding periods of 1915 and 1914 respectively. The colonial demand attained the following importance in the first seven months of the last three years:—

Colonial Group.	1916.	1915.	1914.
	£	£	£
South Africa	172,600	147,583	176,134
British India	45,289	31,927	50,346
Australia	13,963	16,530	29,698
New Zealand	10,038	5,289	8,082

The deliveries made to Australia and New Zealand have left something to be desired this year; but it will be observed that the shipments to Africa and India have been fairly satisfactory. The original principal gold-mining district in the Transvaal has now been exhausted to a large extent; but the outlook further eastward is considered favourable, and this explains the considerable purchases made upon South African account.

ROADS AND PAVING.

TO THE EDITOR OF ENGINEERING.

SIR,—I have read, with very strong appreciation, your extended review of my report on "Street Paving and Maintenance in European Cities," which appeared in your issues of July 14 and 21, pages 32 and 51.

In a study, such as I made, during a period of only 3½ months, and which required in that time over 6,000 miles of travel in the countries of Europe, it is inevitable that there should be omissions and, possibly, superficial observations. The collection of the data which I used occupied a subsequent year of correspondence with the various authorities interested and, consequently, is more comprehensive and exact.

Your *résumé* of my observations and conclusions is, in general, so complete and fair as to leave little room for comment on my part, but I desire to correct one impression which you have, apparently, gathered, possibly because my comments, principally directed toward the answering of specific criticisms which had been made of New York practice, devoted more attention to a comparison between New York and English cities than to those on the Continent. A fuller knowledge of the conditions prevalent here, and perhaps a more careful reading of my report, would not give the impression, which I certainly did not mean to convey, that I think London pavements inferior to those of New York. My statement that "No granite-paved streets (in London) are equal to the best in Manhattan," must be taken in connection with the additional fact shown in my annual reports of our own work, that our best is relatively very limited; most of the latter constructed under my direction are, in my opinion, superior to the granite streets in London, with the exceptions I noted. But, on the other hand, I saw nothing in London as poor as New York's worst, of which, unfortunately, there still remains a great mileage. Specific criticisms had been made of my streets by comparison with those of Liverpool and London, and hence my observations and deductions in reference to those cities dwelt more in detail on some of their shortcomings in order to refute the arguments which had been cited against our work; but you appear to have failed to note my further statement that nowhere in the world have I seen streets the equal of London's wood pavements.

It is for this reason that I selected a view of Whitehall for my frontispiece. While noting, with great admiration, the very fine street surfaces in the newer portion of Berlin, I also called attention to the very light traffic conditions as compared with London and Paris.

The paving engineer in our country is hampered by public and political criticism to an extent not encountered, nor perhaps appreciated, by his colleague in the cities of the old world, and the amateur critic who has enjoyed a little foreign travel and superficial experience with foreign conditions is most annoyingly in evidence.

A subsequent extended investigation of pavements in the cities of the United States, made since my visit to those of Europe, has confirmed my belief that we, in this country, have little to learn about any ways in which we can produce pavements superior to our best, but that we have much room for improvement in the extension of our best type of construction over the large majority of streets in our country, which make our average quality fall below yours, and, particularly, we must improve in the attention to detail and the careful and continuous maintenance in good condition which appeared to me to be characteristic of a majority of the great cities of Europe.

As a result of this investigation, various improvements were introduced in New York, such as the introduction of a better type and the more frequent placing of storm-water inlets, the lengthening of the radius of corner turns at street intersections, and a reduction of curb heights, in all of which respects I found London streets much superior to ours.

I also introduced the method of filling joints in stone block paved streets, which I found practised in Liverpool, of employing a mixture of sand and tar, and, on the wood pavements, changed some details of construction to conform more closely to the English method.

Differences in local conditions in the production of stone block, the different type of wood available for wood pavements and the great variations existing between the classes of material available here and in Europe for the construction of asphalt surfaces, render inevitable many strong contrasts between the best practices on opposite sides of the ocean.

In all these respects such an investigation can merely point out the differences, without demonstrating more than that each appears to be superior for its own locality. But if my study should have led to any increased attention to matters frequently neglected in our design and to a more careful attention to maintaining our streets in their original good condition, it will have served some purpose.

Very truly yours,
HENRY WELLES DURHAM.

Hackensack, N.J., September 6, 1916.

GERMAN COMMERCIAL METHODS IN THE FAR EAST.—United States Customs officials, says *The London and China Telegraph*, have discovered an example of German "ingenuity," by which German manufacturers of dye-stuffs sought to push their wares in China and other parts of the Far East before the war. A package of colours bought by an American speculator in China was received in New York for appraisal. It bore the name of one of the largest German makers of dyes. When a few of the cans were opened, to ascertain the character of the goods, the customs officials found that the cover of each of the cans contained a secret receptacle, holding a silver six-pence.

SOME PROPERTIES OF INGOTS.*

By A. W. and H. BREARLEY (Sheffield).

Crystalline Structure and its Effects.—When steel, or any other crystalline substance, is cast into a mould the freezing commences from the inner surfaces of the mould, supposing the substance is quite fluid to begin with. Assuming the mould to be made from cast iron, and its cross-section a square, then freezing in any plane occurs more rapidly at each of the four corners than elsewhere; and the crystals lying in and about the corners, in consequence of the rapid cooling, are comparatively small ones. Crystals grow also from the sides of the mould, but as their growth sideways is hindered by the adjacent crystals, and their growth forward into the fluid mass is less restrained, they become long and narrow in shape. The crystals growing from any one side of the ingot mould, presuming the interior mass remained fluid, meet crystals growing from the adjacent sides, and a boundary to the cooling effect of each side of the mould is visible on a polished and etched specimen, or on a fractured surface, as junction lines lying diagonally on the square. These remarks are illustrated by Fig. 1 (Plate XXVIII), made from a section of a chromium steel ingot.

In the same way from the bottom of the mould, which is assumed to be flat, crystals grow also upwards until they meet those crystals growing from the sides of the lower part of the mould. It is easy to realise that crystals growing thus from a surface at right angles to the rest would meet obliquely on planes which outline the form of a four-sided pyramid. In the same way the cooling effect of the atmosphere on the free upper surface would cause crystals of the same narrow kind to grow downwards until they also terminated on the surfaces of a four-sided pyramid, assuming, of course, that the fluid material froze quickly, and was not disturbed at the upper end by shrinkage cavities or segregation effects. These considerations enable us to make a sketch diagram illustrating the arrangement of crystals as seen in any longitudinal section cut axially and parallel to a side of the mould (Fig. 2, *a*); in a cross-section cut at right angles to the axis of the ingot, near the bottom (Fig. 2, *b*); and in a similar section cut nearer the middle of the ingot (Fig. 2, *c*) (Plate XXVIII).

The diagonal lines in Figs. 1 and 2 are lines of extreme weakness; partly because they are lines of contact between crystals growing in different directions to each other, and partly because they are coincident with the intersection of the plane surfaces in the ingot which at successive moments were the last to solidify; consequently the planes are rich in segregates and non-metallic impurities (if such, as in steel, can possibly form), they are likely to be occupied by elongated gas cavities, and are also in the position where small cavities caused by contraction stresses would form. The influence of segregate plus contraction cavities would account for a great deal of the observed weakness along the diagonal planes, and it is not possible, apart from this influence, to determine how much of the observed weakness is due only to the crystalline arrangement.

These general observations can readily be verified and illustrated by means of ingots cast with molten stearine. As we have formed a very high opinion of the use of stearine for this and other similar purposes, it is desirable at this stage to refer to the very natural prejudice against applying to steel ingots deductions drawn from the behaviour of stearine. To make experiments with steel is no doubt the most reliable way of learning about the changes which occur during the casting and solidifying of steel ingots; but it entails a costly plant, and molten steel is an expensive material and also dangerous when handled by other than experienced persons. There is also no method of determining the temperature of molten steel with satisfying accuracy, and finally, when ingots are made in the predetermined ways the cutting or breaking of them is both lengthy and costly.

With a few pounds of stearine, a pan of water, a beaker, a Bunsen burner, a few tin moulds, and considerable patience, a great number of observations can be made to illustrate, extend, and also, in some respect, to correct prevailing notions about steel ingots. To increase your respect for observations along these lines and cautious interpretations thereof we need refer only to the very striking operation of removing the base pyramid. Those engaged in making ingots for the manufacture of ordnance are aware that for some years it was usual in many works to cut discs from the ends of ingots or billets and after polishing to etch them. On many such discs the etching revealed a ring of white spots which were really ferrite areas segregated about slag globules. The nearer the base the disc was cut the larger the ring of white spots, which was quite natural on the assumption that the white spots represented the outline of a section cut through the base pyramid. Though the white ring appeared frequently during the few years such observations were being made, no steel-maker, within our experience, would admit that a well-formed cone, such as could be dislodged from a stearine ingot (see Fig. 3, Plate XXVIII), could ever exist in a steel ingot. Eventually, however, a steel ingot weighing about 8 cwt. was cast in such a way that it was held fast at each extreme end. When cooled under such conditions the ingot naturally cracked across the weakest part, and produced the cleanly separated cone reproduced in Fig. 4.*

FIG. 7.—Diagram to illustrate freezing of ingot in straight-sided mould.

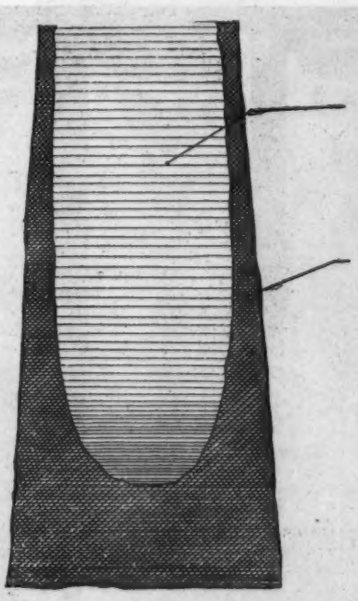

FIG. 8.—Usual representation of a freezing ingot.

In a round ingot the crystals growing from the bottom of the mould are formed into a cone, and in an octagonal ingot they form an eight-sided pyramid. In each case the base pyramid is longer or shorter, depending on the cooling effect of the bottom in relation to the cooling effect of the sides; but generally the base exerts its full effect, because it remains throughout in direct contact with the freezing ingot, whereas the sides of the ingot, soon after solidifying, leave the mould and are thereby partly insulated from its cooling effect by a gaseous envelope. In many cases the pyramid may be separated intact from stearine ingots by pressing a knife into the ingot at right angles to its axis, and splitting layer after layer of the crystals until the peak of and ultimately the entire pyramid is disclosed (Fig. 3). It is instructive by similar means to take ingots to pieces, as it were, in order to observe the effects of segregation and shrinkage cavities localised on their interior surface.

The growth of the elongated crystals originating at the surface of an ingot mould depends on circumstances which appear to be somewhat contradictory, *i.e.*, they are favoured sometimes by slow cooling and sometimes by rapid cooling. So long as the fluid in the interior of the partly solidified ingot remains quite liquid, the crystals already growing from the sides of the mould increase in length as the temperature of the liquid about their extreme ends fall to freezing-point. The act of freezing liberates heat, which is either stored up in the fluid or dissipated *via* the solid crystals, through the sides of the ingot mould. If the crystals are bad conductors of heat the cooling is necessarily slow, whatever the properties of the ingot mould may be, and the fluid in the centre of the ingot remains clear almost to the last drop, whilst needle-like crystals extend to the centre.

But if the crystals themselves are good conductors of heat, then the heat liberated as they form, and also the heat from the fluid interior, is rapidly dissipated through them. In this way the temperature of a large volume of fluid may reach its freezing-point in many places simultaneously, before the crystals growing from the sides can extend to the centre, and thus the interior of an ingot would consist of crystals which had grown from independent centres and were developed in haphazard ways in all directions.

Of crystallisable substances, therefore, which are clearly liquid when cast, those that are very poor conductors of heat will form crystals of the same kind from the surface inwards if allowed to cool undisturbed. But steel, on the other hand, which is a good conductor of heat, will form crystals of the same kind from the surface to the centre of the ingot only if the cooling takes place very quickly or very slowly. In the former case the crystals grow into the clear liquid and extend themselves rapidly as its temperature falls to freezing-point; the result being thin crystals like those seen in Fig. 1 (Plate XXVIII). In the latter case, however, the cooling is so slow that, owing to its high thermal conductivity, the temperature of the fluid mass becomes practically uniform throughout, and then a crystal is as likely to start growing in one place as in another, the result being irregular and approximately equiaxial crystals like those seen in Fig. 5 (Plate XXVIII).

The considerations in these last two paragraphs are closely bound up with the question of casting temperatures, which will be discussed later. But meanwhile it may be said that the elongated crystals occur most frequently in steel cast in chill moulds of narrow section, and the equiaxial crystals in steel cast in dry sand moulds. Obviously there exists a great number of instances where both kinds of crystals occur in the same ingot, as seen in Fig. 6, the exterior crystals being needle-shaped and the interior equiaxial.

Shrinkage and Contraction Cavities.—If we imagine an ingot mould filled with fluid material that could be cooled with perfect uniformity down to its freezing-point, we should find that the level of the fluid would gradually sink as the fluid cooled and shrank. If at this point the fluid were to solidify instantaneously without change of volume we should have a solid ingot. But neither stearine nor steel behave in this manner, and cavities due both to shrinkage of the fluid and contraction of the solid materials exert a great influence on the economic production of ingots, and have to be reckoned with.

An ingot just cast consists of a thin layer of solid metal with a fluid interior whose temperature, we may assume, is practically the casting temperature. The outside length of the ingot has been fixed by the thin solid envelope extending downwards from the highest level of the molten metal in the mould. After a little while the solid envelope has thickened, say, by a millimetre, but before that occurs the fluid metal has cooled, and owing to shrinkage does not now stand at the same level. This has been represented in Fig. 7, annexed, by a step down between the first and second mm. in thickness of the freezing envelope. This process may be thought of as repeating itself in successive and distinct stages as long as any fluid remains in the interior of the ingot, and as a result the central cavity or pipe would be as represented in Fig. 7. As a matter of fact Fig. 7 does represent the general outline of all central pipes in ingots cast in moulds having parallel sides. It differs from an actual pipe only because the thickening of the solid envelope is a continuous process and not an intermittent one; and also because the contraction of the solid envelope and the cooling effect of the atmosphere on the upper surface of the ingot must also be taken into account.

That the freezing of an ingot takes place by a continuous thickening of the solid envelope in planes parallel to the cooling surfaces of the solid is not unanimously admitted. The illustration given in Fig. 8 has been reproduced and approved as a representation of the freezing of steel ingots. It is, however, so far as the author's observations go, a misleading representation of steel ingots and an inaccurate representation of the freezing of any crystalline substance, metallic or otherwise.

If a series of stearine ingots are cast simultaneously from, say, 65 deg. C. in square moulds, in all respects identical and widely spaced apart so that each cools freely, then on piercing the top and inverting one of them after 15 minutes and a further one after each additional 15 minutes, we are left with a series of shells of gradually increasing thickness, but in each case the shape of the cavity out of which the fluid wax was emptied corresponds to that made by the inner walls of the mould.

The same fact can be demonstrated in a more elegant manner by gradually planing down a single ingot parallel to one of its faces. After a few strokes with the plane the sectioned surface exhibits an envelope lying around it. The thickness of the envelope increases as the planing proceeds, just as it did when the ingot was freezing, but it remains quite symmetrical in all parts, as may be seen from the series of photographs reproduced in Fig. 9 (overleaf). Also it thickens parallel

* Paper read before the Iron and Steel Institute, September 21, 1916.

* This experiment was made at the works of Messrs. Thomas Firth and Sons, Limited.

to the cooling surfaces and forms where the bottom and sides intersect a sharp corner, and not the conventional curve seen in Fig. 8.

That steel behaves in a precisely similar manner is known to those furnacemen who have opportunities now and again of seeing ingots broken up that have been upset or otherwise accidentally and completely bled. By way of illustration some photographs are shown in Fig. 10 (Plate XXIX. , representing a crucible steel ingot that was intentionally inverted, and Fig. 11, which represents one much larger ingot from a series prepared by Talbot.* When freezing takes place in the interior of the fluid mass, and not merely by direct thickening of the walls, the above conditions do not apply.

The influence exerted by the size and shape of ingot moulds on the position and dimensions of the pipe will be discussed later, but it is desirable at this stage to consider a feature exhibited by many ingots cast in straight-sided moulds as distinct from taper moulds used with either the narrow or wide end up.

When sufficiently removed from the cooling influence of the closed bottom and the open top of an ingot mould the freezing of any horizontal section of the fluid ingot may be regarded as due to loss of heat through the sides of the mould. When the mould has the same cross-sectional dimensions from top to bottom the crystals growing from the sides in any one plane are as likely to meet in the centre as soon as those growing in any other plane. Now in both commercial stearine wax and in steel a plane of the material may be all but rigid, quite too rigid at the centre to flow downwards, but requiring still to contract over its entire area. The material next the ingot mould is coldest and most rigid, and if the unavoidable contraction cannot pull the flat outer surfaces inwards, the assumed plane must split at the centre, where the material, all but set, offers little resistance. The result is a small central cavity with no material above it fluid enough to flow downwards, and the net effect in an ingot of this kind is a number of cavities roughly spherical in shape, lying in the axis of the ingot. For shrinkage or contraction cavities of this kind an increased length or breadth of feeder head is a doubtful remedy, as in actual practice such cavities occur always in small crucible ingots cast into straight-sided moulds and fed by means of a hot dozzle.

To these two kinds of cavities, viz., the pipe proper and a continuation of the pipe that exhibits itself as a kind of axial sponginess, which, when elongated, may be regarded as a secondary pipe, we must add also cavities, axial or otherwise, arising from the contraction of the hot solid ingot. Such cavities may occur in ingots independent of their shape, and should perhaps be described as contraction rather than shrinkage cavities.

An ingot which has quite set and is still hot contracts in volume on cooling, but as the outer surface of the ingot is hard, and will not yield much, the stress of contraction will be satisfied, wholly or partly, by the formation of internal cracks or cavities in those positions where the resistance is least. In a solid ingot there are certain planes of weakness, due to the arrangement of crystals, which converge from the corners of the mould towards the axis of the ingot. An ingot is therefore easily split along its axis by tensional forces acting at right angles to its length; and it is further induced to yield to such forces by the fact that the ingot is hotter in the centre and weaker also on that account.

This explanation accounts equally well for axial cavities and cracks formed just before or just after complete solidification. As, however, the contraction of the hot solid material takes place continuously in those parts of the ingot already solidified, and does not wait until the entire ingot becomes solid, we may expect to find contraction cavities which were formed whilst the centre of the ingot was still fluid, and in that case they would not, of course, be formed at the centre.

From the moment that a solid envelope is formed about the liquid the crystals growing from the sides of the mould form planes of weakness where they meet each other obliquely, and it is along these planes that contraction cavities are located. They are easily seen when a stearine ingot, cast under favourable conditions, is split diagonally along its length, and may be reproduced photographically, as in Fig. 12, after planing an ingot down until a diagonal section is exposed. These cavities all converge to the centre of the ingot, and appear to depend on and originate from an axial cavity. That they are not developed in that order, but begin to form whilst the centre of the ingot is quite fluid, could be shown by bleeding partly broken ingots and bisecting the solidified shell diagonally.

There are several reasons why contraction cavities should lie along these planes, extending from the corners to the centre of a square ingot. In the first place the planes are formed by the intersection of surfaces of the ingot which at successive moments were the last to solidify; and about the angle thus formed the contraction stresses are localised, with the consequent danger so often exhibited in the hardening of steel tools cut with sharp corners, as keyways, &c. Then any absorbed gases liberated at the moment of setting and impurities likely to segregate are also to be found in abnormal amounts along these planes. It needs, therefore, nothing but a favourable concourse of circumstances to produce large cavities or even extended cracks; and in average cases it needs very little force in addition to the ordinary contraction stresses to cause rupture. (See Fig. 13, Plate XXIX).

But in addition to cavities that are obvious to the naked eye it is not unusual in steel ingots to find cracks running between the crystals at right angles to the surfaces of the ingot mould. These cracks are discoverable by direct microscopic observation as in Fig. 14, Plate XXIX), which is an enlargement of part of Fig. 1; or indirectly by making use of corrosion effects.

Cracks may be revealed in large numbers by immersing a disc of steel in a 10 per cent. solution of hydrochloric acid. The acid attacks the metal most vigorously along the edges of any existing cracks, and eventually the crack widens into a visible cavity. This effect is shown in Fig. 15, which represents a disc cut from a 4-in. square ingot; it will be noted that the length of the cavities lie in the same direction as the length of the crystals between which they occur. Cavities of a similar kind which originate from segregated areas may also be developed by extended pickling; but there are decisive means of distinguishing one kind from the other, and confusion is not likely to arise if careful observation be made of the scattered distribution of the former compared with the occurrence in groups of the latter.

Radial cracks may occur in steel ingots which do not exhibit elongated crystals on a fractured surface. When a disc cut from a large steel ingot weighing, say, 40 or 60 tons, or from a circular billet which has been forged from such an ingot, is polished and etched with a very dilute solution of nitric acid in alcohol, the intercrystalline cracks are located by the evolution from them of small gaseous bubbles. That the gaseous bubbles may escape more easily it is advisable to arrange the disc with the polished face in a vertical position and wash it over by means of a broad camel-hair brush with the etching fluid; small strings of bubbles then run with the solution down the face of the disc from one or two or maybe a score or more cracks. The objectionable features of contraction cracks are emphasised by segregation or slag occlusions, and these, as well as the amount of hot work done in the forging, determine whether or not the crack will weld up. Fig. 16 (Plate XXIX) represents the kind of radial crack we are speaking of as it existed in a 30-in. billet. The light-coloured spot is a transverse section of a miniature ghost, and when these occur in groups the cracks will generally pass from one to the other (see Fig. 17), as the small slag globules or streaks of slag, around which the ghost forms, have already broken the continuity of the metal.

If the material in which the cracks appear is not weldable, then it is also not forgeable, and will crumble under the hammer. This explains why some alloy steel ingots may not be forged, whereas others of the same composition, but melted and cast under different conditions, forge fairly well. The number and magnitude of the cracks would obviously be increased if the steel had air-hardening properties.

a b c d e

FIG. 9.—To illustrate symmetrical freezing of ingots.

Casting Temperatures.—When a crucible steel ingot breaks with a needle-like fracture (Fig. 2, c) it is said to be "scorched," and scorching is said to be due to the molten steel having "had too much fire." A furnaceman does not generally commit himself by saying whether the steel has been for too long a time in the furnace or at too high a temperature. He may not know;* but he does know a scorched ingot can be broken across with remarkable ease, and that he will very likely get into trouble if he makes many such ingots.

Scorched ingots are objectionable only on account of their fragility, due to arrangement of the crystals in definite directions, and the extended contraction cavities which may arise. This is, of course, a serious objection, because unless the scorched ingot, after reheating, is very carefully, and, to begin with, very gently forged the weakness between the well-developed crystals will cause cracks to form at the corners of the forged bar. But apart from obvious defects like this, the quality of the steel is neither better nor worse for having shown the scorched appearance in the ingot.

The characteristic appearances of both the inside and outside of "cold-cast" ingots are understandable after seeing a stearine ingot cast into a glass mould. First as to the outside. As the wax, per assumption, has

* Journal of the Iron and Steel Institute, 1913, No. I, page 30.

* Text-books say: "If kept too long in the furnace the steel will teem dead and the fracture of the ingot will have what is known as a 'scorched look.'" This is misleading.

already reached its freezing temperature it solidifies immediately on contact with the bottom and sides of the mould. It freezes also over the free upper surface into a crust of crystals, and as more fluid wax is added the liquid level and solid crust rise together, the latter generally increasing in thickness. But the crystal crust has solidified into a piece with the sides of the ingot, and as the fluid wax rises it pushes the crust upwards most effectively where it is least restricted, *i.e.*, in the centre. The crust, therefore, becomes increasingly convex until, broken by upward pressure of the fluid wax,

FIG. 17.—Easy passage of radial crack between slag occlusions.

The internal structure of a "cold-cast" ingot is unlike that of a hot-cast ingot, because in the former case the centres of crystallisation are dispersed throughout the entire ingot instead of being confined to the inner surfaces of the mould or the solid metal envelope already formed from it. The crystals therefore do not grow in planes but in all directions, and form spherical clusters floating in the fluid like seed-pods of a dandelion floating in still air. The clusters of solid crystals are heavier than the fluid steel and tend to sink to the bottom of the mould.

We have said that an ingot freezes by a gradual and

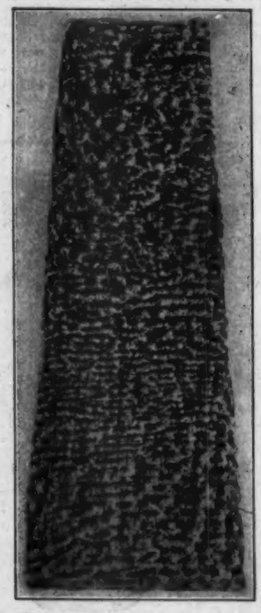

FIG. 18.—Appearance of surface of "cold cast" ingot.

inverting the ingot or by passing a hot rod through the base of the ingot. By the first-named procedure the crystal groups are disturbed, and by the last-named procedure some of the fluid solidifies in passing through the thick cooler base of the ingot. But in either case the information sought can be easily interpreted apart from these interferences, as may be seen by reference to Fig. 20 (below), which represents wax ingots cast from 55 deg. C. and bled through the top end after varying lengths of time.

The formation of free crystals in the fluid material adds considerably to the mechanical strength of an ingot by interfering with the growth of elongated crystals at right angles to the sides of the ingot mould, *i.e.*, by suppressing the scorched appearance. This is apparent

FIG. 19.—Antimony crystals floated to surface of partly solidified alloy.

a *b* *c*

FIG. 20.—Crystals deposited from partly-solidified ingot on base and sides.

a new surface is formed. In the act of forming a new surface the fluid wax strikes the glass mould and is frozen before it can fill up the lowest part of the convexity, and hence the surface of the stripped ingot is a series of rings where it has been in contact with the mould, and a series of depressions lying alternately between them where it has not been in contact with the mould. (Fig. 18, above.)

Pieces of broken crystalline crust are washed into the fluid material, and form independent centres of crystallisation in both stearine and steel. But in steel they may also form blowholes, due to a gas liberation promoted by their oxidised surfaces, and also irregular lines of weakness which may not weld up completely in the subsequent forging.

uniform thickening of its solid walls in planes approximately parallel to the inner surfaces of the ingot mould (see Fig. 9). But this statement applies only when the conditions are such that the interior fluid is a perfect liquid. If free crystals form in the liquid independent of the cooling effect of the mould they will rise, as in antimony-lead alloys (see Fig. 19, above), if they are lighter, or sink, as in stearine and steel, if they are heavier than the mother liquid. In the latter case the base of the ingot will be thicker, at any moment during solidification, than can be accounted for by direct cooling effects in those positions.

The presence of separated crystals in stearine ingots can be demonstrated in two or three ways. One way consists of emptying out the fluid portion either by

in stearine ingots on attempting to split them diagonally, and particularly in attempting to remove the base pyramid as already described. It is apparent also in small steel ingots by the greater effort required to top them. In large steel ingots the formation of free crystals is also made apparent by the very marked difference in carbon content between the top and bottom of the ingot—in fact it is impossible to cast a very large ingot of, say, 40 tons or over from the same ladle and maintain, apart from localised segregation, a uniform amount of carbon throughout its length. The steelmaker has therefore to compromise between two evils, *i.e.*, he may either cast hot and emphasise local segregations, shrinkage cavities, and contraction cracks, or cast cold and widen the difference in composition between the top and bottom of the ingot. The crystals first formed in fluid steel contain, of course, less carbon than the remaining mother liquor, and this explains why the settling of the crystals to the bottom of the ingot widens the variation in composition.

To express in definite figures the influence of varied casting temperature on the mechanical properties of steel would involve an enormous amount of labour and require great experimental skill. It would, for example, not suffice to machine test-pieces out of an ingot, because the defects to be looked for would sometimes be in the test piece and at other times not; and even if it were practicable to machine always a test-piece containing a typical defect it would be quite impossible to arrange for the defect to occupy the same relative position in every test-piece, and therefore the tensile properties of the test-pieces would vary amongst themselves without indicating any corresponding variation in the ingots from which they had been prepared.

The least objectionable form of test-piece is the ingot itself. But as commercial ingots are not amenable to the requirements of testing methods and machines, and as, further, there is no handy means whereby the casting temperature of steel can be accurately measured, we are obliged to content ourselves with general statements to the effect that the casting temperature of steel may be too high or too low to produce the best results. When it is remembered that the correct, *i.e.*, the best casting temperature differs from one material to another, and for the same material according to the weight and dimensions of the ingots, to say nothing of foundry castings, there appears to be ample room for the exercise of the art as distinguished from the science of steelmaking.

But in making wax ingots the variable conditions are controllable with that degree of accuracy which yields confirmatory results from duplicated tests, and as the behaviour of stearine wax in so many respects is comparable to the behaviour of steel, it may be possible by its aid to confirm the general statements alluded to in the preceding paragraph, and also, by analogies carefully drawn, to add something to it.

Apparently the least troublesome way of casting a series of ingots from varying temperatures is to melt a large beakerful of stearine and cast one ingot after another as its temperature falls. But the application of

this method leads to very erratic results, because, in passing over the colder lip of the beaker, the wax solidifies and, in the worst cases, small pieces of solid wax are carried forward into the ingot. These are comparatively harmless when the temperature of the cast ingot is sufficiently high to remelt them, but otherwise they cause what should be a scorched ingot to appear granular or finely crystalline on its fractured surface.

To avoid this irregularity use may be made of glass tubes, 7 in. long by ¾ in. in diameter, which have at each end a well-fitting perforated cork. Pieces of thin glass tubing fit into the corks, the one at the lower end being drawn out to a fairly fine point, and the one at the upper end being provided with a few inches of rubber tubing and a spring clip (see Fig. 21).

The lower drawn-out end of the glass tubing is kept at the temperature fixed for the ingot next to be cast,

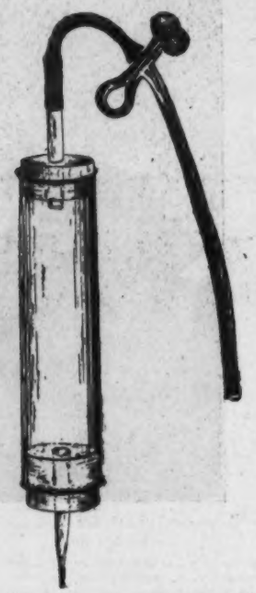

FIG. 21.—Arrangement for casting wax test ingots.

so that when immersed in the fluid wax the opening is not stopped up. The molten wax is drawn upwards by suction on the rubber tube until the mould is nearly full. The pinch-cock is then closed; the end of the lower projection is dipped into cold water to solidify the wax and so close the opening; the upper cork, together with the rubber tubing and pinch-cock, are removed, and the mould is allowed to stand quietly in a vertical position until it becomes quite cold. Series of ingots are made successively in this way as the temperature of the melted wax sinks; and it is easy to arrange for the temperature to fall at the rate of, say, 1 deg. C. in 15 minutes, thus permitting duplicate or triplicate ingots to be made at each chosen temperature.

The simple piece of apparatus shown in Fig. 22 may be used to test the strength of the ingots made as described. The ingots rest on supports 4 in. apart, and midway between the supports the pan is hung into which mercury is allowed to flow from a graduated burette, or into which small leaden shot is poured until the ingot breaks. The burette is then read off or the weight of shot used is noted in order to arrive at the breaking load in grammes. As the results are merely comparative the net breaking loads on the ¾-in. circular ingots used are given in the tables below and plotted as a curve in Fig. 23.

Casting Temperature. Degrees C.	Breaking Load in Grammes.					
	1.	2.	3.	4.	5.	Average.
80	1,618	—	—	—	—	—
75	1,671	—	—	—	—	—
70	1,551	—	—	—	—	—
65	1,229	—	—	—	—	—
64	1,292	1,155	1,208	—	—	1,218
62	1,048	1,009	—	—	—	1,029
60	1,224	1,274	1,168	—	—	1,222
58	982	1,009	1,088	—	—	1,026
56	1,459	1,155	1,605	1,830	—	1,512
54	2,783	2,995	2,783	3,193	3,127	2,938

	Grammes.
One minute after reaching 54 deg. C.	3,250
Two minutes after reaching 54 deg. C. ..	2,224
Three " " " ..	3,021
Four " " " ..	2,995
Five " " " ..	3,101
Six " " " ..	2,929

The most noticeable feature in this series of results is the great increase in strength between those ingots cast respectively at 56 deg. and 54 deg. C., the latter being almost twice as strong, and this is confirmed by the appearance of the fractures, which show a marked difference within this short range of casting temperature. The ingots cast at 54 deg. C. have a granular or finely crystalline structure, whilst those cast at 56 deg. C. and over show scorch. This observation is quite in line with the behaviour of small steel ingots, both as regards appearance of fractured surfaces and mechanical strength.

The increase in strength when the casting temperature reaches 65 deg. C. is also notable and not especially difficult to understand. It is to be expected that, all other conditions being equal, a rise in the casting temperature alone would cause the ingots to become gradually weaker, but a rise in casting temperature disturbs the other conditions, and more especially the rate of cooling, so that an ingot cast with wax at 58 deg. C. into a thin mould might at once have a solid envelope formed around it by the cooling action of the mould;

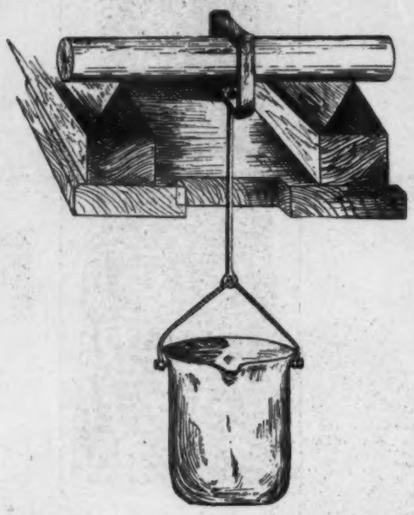

FIG. 22.—Arrangement for testing strength of wax ingots.

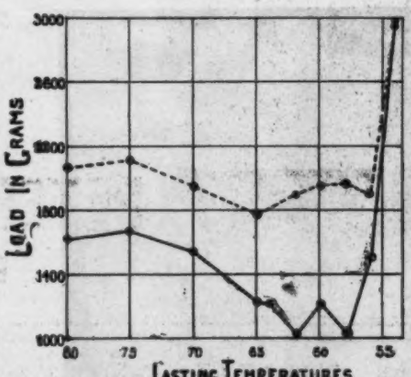

FIG. 23.—To illustrate influence of casting temperature on strength.

whereas when cast from a higher temperature the heat lost in cooling the mould might depress the temperature of the fluid wax to 58 deg. C. without causing a solid envelope to form around it. The rate of cooling in the two cases would then vary, and the latter would be more or less disposed to form the stronger equiaxial crystals, depending on the thermal conductivity, specific heat and mass of the ingot mould, and on the relative thermal conductivity of the fluid and solid ingot material. It is therefore likely that at some temperature well above the freezing temperature a wax ingot or a steel casting would become stronger, but the rise in strength would not occur at the same temperature, of course, except under identical experimental conditions.

(To be continued.)

COAL IN ICELAND.—A Danish-Icelandish syndicate has been formed for the exploitation of coal in Iceland, and judging from a report which has been published, prospects appear satisfactory. The site has been penetrated to a depth of 32 m. (105 ft.). A Swedish expert connected with the research work states that the coal is as good as British steam coal, and the deposits are expected to extend over an area of some 40 sq. miles. Geological scientists, however, maintain that coal proper cannot be found in Iceland, and that the formation must be a lignite formation. A couple of hundred tons have so far been broken.

CATALOGUES.

Fans and Blowers, Dust-Collecting Plant, Crushing Machinery, &c.—In order to show the wide range of their products the Sturtevant Engineering Company, Limited, of 147, Queen Victoria-street, E.C., have issued a pamphlet illustrating a few representative examples of fans and blowers, heating and ventilating plant, drying plant, dust-collecting apparatus, forges, mechanical draught installations for boilers, steam engines and turbines, and crushing and grinding plant for minerals and other materials. Further particulars of these products are given in separate catalogues and other publications issued by the firm from time to time.

Gas and Oil Engines.—We have received from the Chicago Pneumatic Tool Company, of Fisher Building, Chicago, Ill., U.S.A., a bulletin relating to the applications of their "Giant" gas and fuel oil engines. Particulars are given of pumping sets of the centrifugal and reciprocating types, electric generating sets, blowing and exhausting plants, hoisting plants, air compressors, and other machinery driven by engines ranging from 12 to 160 h.p. The Consolidated Pneumatic Tool Company, Limited, of 9, Bridge-street, Westminster, S.W., are agents for the Chicago Company for this country and also for Spain and Portugal.

Traction Engines and Road Rollers.—A catalogue section devoted to traction engines and road rollers has come to hand from Messrs. Marshall, Sons, and Co., Limited, of Gainsborough. Specifications and full particulars are given of traction engines of 5, 6, 7 and 8 nominal horse-power, and of road rollers of 6, 8, 10 and 12 tons weight, both traction engines and rollers being listed in the single-cylinder and compound types. The catalogue also deals with convertible engines, which can be easily arranged for either haulage work or road-making, as well as with scarifying apparatus, road wagons, living and sleeping vans, water carts, and other accessories. A number of illustrations reproduced from photographs showing the engines at work in different parts of the world are included in the catalogue.

Hydraulic Machinery.—Messrs. Fielding and Platt, Limited, of Gloucester, have brought out their hydraulic machinery catalogue in Russian and French in one volume. This runs to 225 pages, and practically each left-hand page is devoted to an illustration, while on the corresponding right-hand page the description appears in the two languages. The firm's experience of hydraulic machinery reaches back 60 years, and the volume represents the most valuable part of it. It includes accumulators, capstans, punching and shearing machines, tube-bending machines, elevators, cranes, lifts, intensifiers, riveting machines, pumps, presses of all kinds and sizes and valves. The book is thoroughly well got-up and appears at a most opportune time for the convenience of our allies and for the benefit of our trade. Incidentally, it will assist those who are acquiring a knowledge of technical Russian.

Forced-Draught Furnaces.—Messrs. Meldrums, Limited, of Timperley, Manchester, have sent us an attractive catalogue relating to their well-known forced-draught furnaces, and illustrating the application of these furnaces to Lancashire and Cornish boilers, water-tube boilers, brewers' coppers, metallurgical furnaces, &c. It is mentioned that over 16,000 of these furnaces, representing an aggregate steam production of considerably over 2,000,000 h.p., have now been fitted. The system is fully described, and its advantages pointed out, special attention being drawn to the fact that low-grade fuels can be burnt effectively, and that the fire is always under complete control. The average consumption of steam in the jets is given as 3 to 4 per cent. of the steam generated. Numerous testimonial letters from users are printed in the catalogue, and some examples of other products of the firm are also illustrated. Among the latter are included stokers of the sprinkling and coking types, refuse destructors, and steam-jet apparatus for raising liquids, air compressing and exhausting, and many other purposes.

Saw-Mill Accessories, &c.—Messrs. A. Ransome and Co., Limited, of Stanley Works, Newark-on-Trent, have sent us a copy of an illustrated handbook of accessories for saw-mills and wood-working machinery. The publication, which contains 150 pages bound in paper-covered boards, with cloth back, states prices for band-saws, circular saws, frame saws, "drunken" saws, &c., and also gives particulars of swages, side dressers, setting tools, brazing apparatus, and other appliances for keeping saws in working order. Planing and moulding cutters, cutter blocks, grinding appliances for knives and cutters, mortising and boring tools, tenoning tools, saw and cutter guards, and accessories for power transmission, are also dealt with. A very valuable feature of the publication is the inclusion in it of a great number of useful notes on the care and treatment of saws, and the methods of keeping such articles as hollow-square chisels, mortise chains, &c., in good condition. The practical nature of these notes will certainly appeal to all users of wood-working machinery. A number of notes and tables on horse-power transmitted by shafting and belting, electric driving, equivalents for converting British and metric measures, &c., will also be found useful. The handbook is well printed and illustrated and conveniently arranged, so that a considerable demand for it is to be anticipated.

MORE MANGANESE.—Prospectors drilling for iron ore in the Crystal Falls, Michigan, recently struck 5 ft. of manganese ore running up to 35 per cent. manganese. The deposit is considered small, but additional drilling is being carried on. One hole was put down 1,100 ft. without meeting with manganese.